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Draft Environmental Impact Statement Golden Sunlight Mine

COOPERATING AGENCIES:

Montana Department of Natural Resources and Conservation
U.S. Army Corps of Engineers

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BLM MISSION STATEMENT

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APPENDIX A

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APPENDIX A

LONG-TERM WATER MANAGEMENT AT GSM

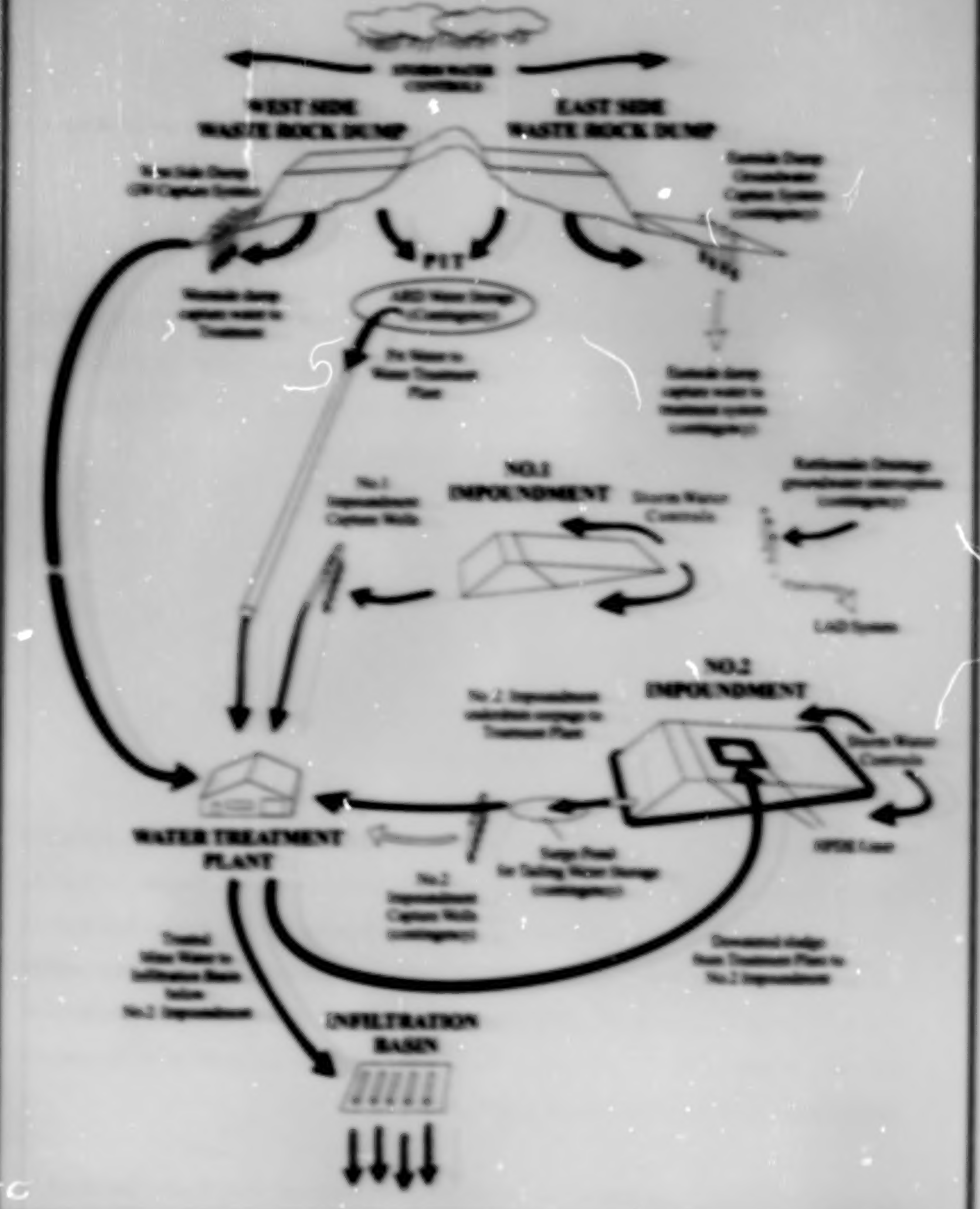
1.0 OVERVIEW OF WATER MANAGEMENT COMPONENTS

Water management at Golden Sunlight Mine consists of site wide monitoring of groundwater and storm water quality, groundwater and storm water controls, and water treatment. Water management requirements vary in different portions of the mine site and can be divided into the following components based on major mine facilities:

1. Open Pit
2. Impoundment No. 1
3. Impoundment No. 2
4. East Waste Rock Dump
5. West Waste Rock Dump
6. Post-Operational Water Treatment Facilities

A schematic diagram illustrating expected water handling relationships at the mine site under the EIS Proposed Action is shown in Figure 1. Some potential sources of water, such as the waste rock dumps, are not anticipated to generate any impacts for tens or even hundreds of years. This report therefore, summarizes GSM's plan for addressing long-term water quality issues. It includes a description of the estimated quantity and quality of water that could be generated in each of the facility areas. The plan also includes proposed contingencies for monitoring, capture and treatment of impacted water.

The potential quantity and quality of feed water to the treatment plant is also described, as well as generalized estimates of capital and operational costs for long-term water handling


STORM WATER CONTROLS
WEST SIDE WASTE ROCK DUMP
EAST SIDE WASTE ROCK DUMP
West Side Dump GW Capture System
Eastside Dump Groundwater Capture System (contingency)
PIT
Westside dump capture water to Treatment
ARD Water Storage (Contingency)
Pit Water to Water Treatment Plant
Eastside dump capture water to treatment system (contingency)
NO.1 IMPOUNDMENT
No.1 Impoundment Capture Wells
Storm Water Controls
Rattlesnake Drainage groundwater interception (contingency)
LAD System
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APPENDIX A	SCHEMATIC OF LONG-TERM WATER MANAGEMENT AT GOLDEN SUNLIGHT MINE	FIGURE 1

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and treatment. Ambient water quality in discharge areas and compliance limits associated with specific discharges are addressed in EIS Appendix B.

2.0 WATER MANAGEMENT COMPONENTS BASED ON PROPOSED ACTION

The water management components shown in Figure 1 and described below are based on GSM's proposed action. The analysis focuses primarily on water handling requirements within disturbance areas. GSM also has a stormwater management system that uses a system of berms and swales to promote infiltration and minimize runon & runoff in disturbed and reclaimed areas. The present operational stormwater management system will become a permanent control system at closure. Details regarding GSM's operational and post-closure storm water control systems are provided in GSM's Storm Water Pollution Prevention Plan (SWPPP) and Reclamation Plan, respectively. These plans are on file with the Department of Environmental Quality (DEQ) and the Bureau of Land Management (BLM).

2.1 OPEN PIT

Quantity of Discharge. Under the proposed action, the open pit would be excavated to an elevation of approximately 4700 feet. A post-mining water level elevation of 5050 feet would be maintained in the pit by continuous dewatering. This elevation is approximately 200 to 500 feet lower than premining conditions, and will produce a groundwater depression that will act as a hydrologic sink to groundwater flow. Groundwater flow will therefore, be directed towards the pit dewatering system.

Excess water collecting in the pit will require treatment before it is discharged back into the downgradient groundwater system. It is estimated that the pit will take approximately 30 years to fill to an elevation of 5050 feet. During this filling period there would be no outflow from the pit. Once water levels approach the 5050 feet elevation dewatering would be required to prevent further filling and potential outflow. At an elevation of 5050 feet, the pit pond is estimated to have a net rate of inflow of approximately 54 gpm. Barge-mounted pumps would route this water to the proposed treatment system. Seasonally, inflow to the pit is estimated to range from 15 to 140 gpm, with short term rates of inflow up to 250 gpm. The pit pond elevation will be regulated to provide sufficient storage volume to accommodate seasonal or yearly variations in inflow. A 30 foot change in stage is estimated to be sufficient to accommodate an entire year of runoff at approximately 550 gpm (10 times the average rate of inflow).

Inflow estimates for the pit are based on a detailed water balance model (GSM, 1995 Application for Amendment to Operating Permit 00065) which was developed by GSM to assess long-term treatment needs. Assumptions used in the water balance analysis are documented in GSM's 1995 Hard Rock Mining Permit Application and are summarized below.

- Pit inflow estimates are based on a bulk permeability of the bedrock of 1x10[illegible] cm/sec and regional recharge rates of 10 to 20% of the annual precipitation. Higher permeabilities were simulated in the model but could not adequately reproduce existing hydraulic gradients or inflows.
- The surface water component of the water balance was calculated based on mean monthly precipitation and temperature data collected at Golden Sunlight Mine. The model assumes all rainfall runoff from the pit walls will report directly to the pit pond with no diversion of runoff from the pit area. A 100% runoff factor was assumed for the pond area and 30% runoff factor for surrounding benches. Snowmelt runoff is accounted for in the surface water inflow estimates.

The pit inflows estimated by the water balance model generally appear to be conservative compared to observed dewatering flows in the pit area. The pit bottom is presently at approximately 5200 feet and has an average combined groundwater and surface water inflow of approximately 35 gpm based on 1996 pit dewatering records. The pit inflow model had

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predicted 33 gpm groundwater inflow. This predicted inflow estimate is conservatively high compared to observed inflows since it does not include surface water inflow.

Pit Water Quality. The water quality of pit water was previously estimated as part of a treatment system design analysis (Attachment A-1). Pit water quality estimates have been updated here to include water quality data from the Stage III pit pond. Predicted pit water quality is summarized in Table 1.

Contingencies. Predicted pit inflows from modeling are believed to be conservative (i.e. over estimating the inflow) based on recharge assumptions and by comparison with observed flow conditions in the pit. Actual pit inflow rates and the extent of groundwater capture can vary from model predictions if hydrologic conditions vary significantly as the pit is advanced. GSM has included an additional 20% flow contingency. Long-term treatment requirements also will be re-evaluated before the permanent treatment system is built.

Depressed water level elevations in the pit will cause the pit to act as a hydrologic sink, therefore, no groundwater outflow is predicted from the pit under the Proposed Action. Monitoring will be conducted from in pit area monitoring wells (Section 4.0) to document capture effectiveness. The location of pit area monitoring wells are shown in the monitoring plan in Attachment 2 to this Appendix and are described in GSM's 1996 annual monitoring report. Since provisions for groundwater monitoring and capture are already provided in surrounding dump areas, no additional contingencies for groundwater capture are proposed for the pit area.

TABLE 1. PIT WATER QUALITY SUMMARY

SOURCE	pH	TDS	Ca	Mg	Na	K	SO4	NO3+NO2-N	Al	As	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Ohio Adit (1)	2.7	NA	NA	NA	NA	NA	NA	1.31	NA	0.012	0.1267	<0.02	19.08	14.1	0.0079	NA	<0.001	1.65	0.0063	<0.005	19.25
Ohio Adit (2)	2.6	20600	510	1760	46	NA	13600	NA	139	1.27	0.160	NA	22.5	2090	0.01	51.6	NA	NA	NA	NA	140
Stage II Pit Water (3)	2.6	13900	467	1170	74	NA	8720	NA	135	0.105	0.267	NA	60.9	680	<0.01	50.8	NA	NA	NA	NA	78
Stage II Pit Water (6)	2.4	15900	475	1300	75	2	11000	7.15	160	0.202	0.556	NA	66.7	1130	<0.01	40.2	<0.001	11.2	<0.005	<0.005	106
Stage III Pit Water (8)	1.5	14500	491	2192	65	28	10900	24.1	92	0.076	0.080	<0.002	10.3	922	0.279	28.5	<0.0002	7.4	0.023	<0.004	81
High Wall Seep (4)	2.5	26100	126	574	91	NA	18100	NA	1420	1.49	3.91	NA	343	5890	0.25	29.6	NA	NA	NA	NA	288
High Wall Seep (7)	2.7	7540	322	692	50	NA	4400	NA	26	0.05	0.017	NA	2.56	476	0.01	692		NA	NA	NA	219
Feed Water (5)	3.0	10540	450	908	64.4	NA	5960	NA	57.6	0.099	0.026	0.089	60	1024	1.09	46.6	NA	3.09	NA	NA	51.2
Average	**2.7**	**15600**	**400**	**1299**	**59**	**15**	**10240**	**10.9**	**392**	**0.481**	**0.643**	**0.089**	**75.9**	**1576**	**0.274**	**126**	**0.000**	**5.84**	**0.015**	**0.000**	**98.6**
Minimum	2.4	7540	126	574	46	2	4400	1.31	26	0.012	0.017	0.089	2.56	14.1	0.0079	28.5	0	1.65	0.0063	0	19.25
Maximum	1.5	26100	510	2192	74	28	18100	24.1	1420	1.49	3.91	0.089	343	5890	1.09	692	0	11.2	0.023	0	288

Notes:

(1) Source: Outline of Bond, January 6, 1992 letter from Alan Storey to Pat Plantenberg, MDSL.

(2) Source: July 1993 Ohio Adit water quality from September 29, 1993 memo from N. Gallagher to F. Foster.

(3) Source: July 1993 Stage II Pit water quality from September 29, 1993 memo from N. Gallagher to F. Foster.

(4) Source: June 1993 High Wall Seep 5700-1 water quality from September 29, 1993 memo from N. Gallagher to F. Foster.

(5) Water treatment plant feed water May 16, 1994.

(6) August 13, 1993 Stage II pit water quality analysis.

(7) Source: June 1993 High Wall Seep 5350-2 water quality from September 29, 1993 memo from N. Gallagher to F. Foster.

(8) Source: Average of Stage III pit water quality analyses from May 1991 through April 1997.

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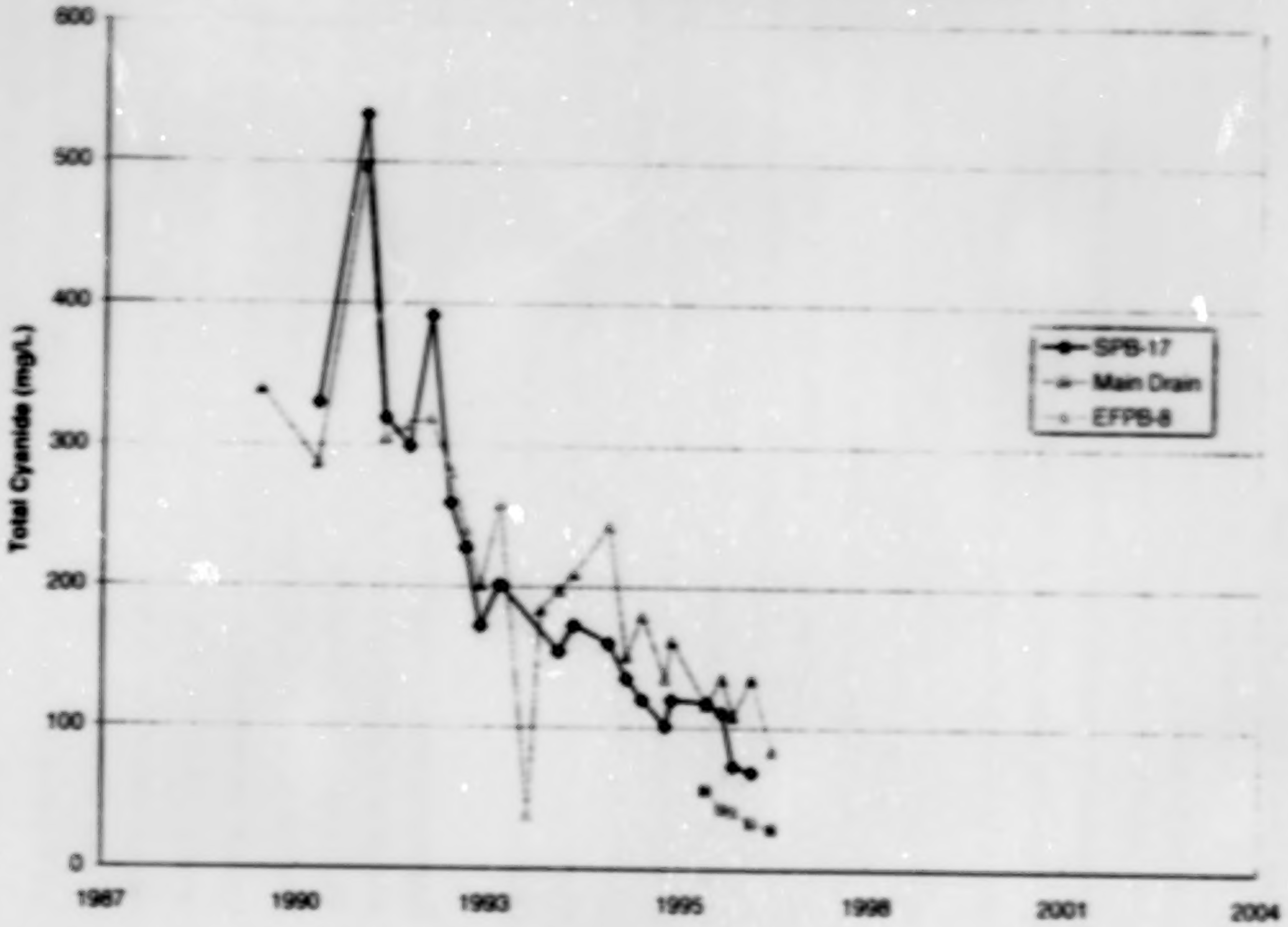
2.2 TAILING IMPOUNDMENT NO. 1

Tailing Impoundment Seepage Rates Decommissioning began on Impoundment No. 1 when the No. 2 Impoundment was brought on-line in 1994. The tailing in Impoundment No. 1 is presently draining. Since decommissioning began, the rate of seepage captured from the EFPB and SPB pumpback wells has declined from 572 gpm in 1993 to 266 gpm in 1996. This decrease in pumpback rates reflects a reduction in tailing pore water seepage combined with upgradient groundwater in the Rattlesnake Gulch Hydrostratographic unit. Excess pore water in the tailing is expected to completely drain by mine closure.

Post-reclamation seepage rates from seasonal infiltration of precipitation through the reclaimed impoundment surface are predicted to be minimal (0.25 in/yr) and would result in only 2 gpm of seepage over the 150 acre impoundment (EIS Section IV). However, GSM will maintain existing pumpback wells as a conservative measure. For purposes of estimating long-term treatment requirements GSM has assumed an inflow rate of 200 gpm (most of which is Rattlesnake groundwater) to the treatment plant due to continued use of the capture wells. This is a conservatively high flow estimate based on present pumpback trends. Ultimately, upgradient groundwater interception combined with tailing dewatering should result in minimal flows requiring capture and treatment.

Potential Seepage Quality As the tailing dewaters and oxidizes, tailing pore water quality is anticipated to change from high pH water containing cyanide, to lower pH ARD water. Water quality data show a trend of declining cyanide concentrations in pumpback well water from 300 to 500 mg/L in the early 1990's to less than 100 mg/L at present (Figure 2). Cyanide concentrations will continue to drop as the tailing drains and ARD conditions develop. However, once Impoundment No. 1 is successfully dewatered and reclaimed, seepage rates will be minimal (approximately 2 gpm) and long-term capture and treatment may not be needed for this area. However, GSM has conservatively, included monitoring and continued operation of the pumpback system in its long-term water management plan in the event that water quality impacts are not fully mitigated at the end of mining.

FIGURE 2
CYANIDE TRENDS IN IMPOUNDMENT NO.1 SEEPAGE



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Contingencies The underdrain system that presently exists beneath the Buttress Dump immediately upgradient of the No. 1 Impoundment will intercept shallow groundwater in the Rattlesnake unit reducing the potential for groundwater flux through of the tailing. As a contingency measure GSM could resume operation of the existing Rattlesnake groundwater interception wells (used during buttress underdrain construction) to further ensure that groundwater does not come in contact with tailing material. Also for surge capacity, and temporary storage GSM can use existing lined overflow basins south of Impoundment No. 2. These provide 40 million gallons storage for tailings pumpback well water.

2.3 TAILING IMPOUNDMENT NO. 2

Tailing Impoundment Seepage Rates Tailing Impoundment No. 2 is a 140 acre lined (HPDE and compacted clay) impoundment with a fingerdrain system over the liner for seepage collection. At closure, tailing water will be spray-evaporated over the impoundment area to facilitate dewatering and breakdown of any residual cyanide. When the final reclamation cap is in place, it is designed to achieve near zero infiltration (0.25 in/yr), resulting in an estimated total seepage rate on the order of 2 gpm. For purposes of estimating treatment flows, GSM has conservatively assumed 10 gpm of seepage from the underdrain system, which approximates natural recharge rates in the surrounding Tertiary sediments. Existing lined overflow basins to the south of Impoundment No. 2 will be used to meet any short term storage requirements for either Impoundment No. 1 or Impoundment No. 2 inflow. These ponds have a surge capacity of approximately 40 million gallons (7.6 years of 10 gpm inflow).

Seepage Quality Like Impoundment No. 1, tailing porewater is anticipated to develop ARD characteristics as the tailing dewaters and acidifies. GSM will be installing an INCO system for cyanide destruction in the Impoundment No. 2 process loop. This and the spray evaporation will eliminate the need for post-closure cyanide treatment. ARD may ultimately result in seepage quality similar to pit water or waste rock dump seepage.

Contingencies GSM has conservatively assumed a 5 fold increase in the predicted long-term seepage rate for the No. 2 Impoundment under the proposed action (from 2 gpm to 10 gpm). Water quality compliance will be documented through long-term monitoring in downgradient monitoring wells as described in Appendix B. Existing T2PB wells immediately downgradient of the impoundment (Attachment A-1) will be used as a contingency groundwater pumpback system should long-term monitoring indicate water quality compliance concerns associated with seepage from the liner systems beneath the impoundment and seepage collection basins. Based on the relatively low permeability of the underlying hydrostratigraphic unit (10^{-4}-10^{-6}cm/sec), the potential rate of groundwater capture would be to the order of 15 gpm. It should be noted that unlike impoundment No. 1, No. 2 does not have an underlying alluvial groundwater system.

2.4 EAST WASTE ROCK DUMP

East Waste Rock Dump Seepage Estimates Based on excavations of the existing northeast dumps during the 1994 ground movement, and dump moisture monitoring by GSM, the waste rock dumps do not appear to be discharging seepage to groundwater. Modeling in the EIS (Appendix J) estimates that any seepage to groundwater from infiltrating precipitation in the East Waste Rock Dumps would not occur for 50 to 350 years, due to the expected low infiltration rate through the reclaimed dumps (0.03 gpm/acre) and the presence of hundreds of feet of intervening unsaturated material above the water table. In theory, seepage from the dumps could ultimately occur, eventually reaching a total of 10 gpm based on the predicted long-term infiltration rate of 0.5 in/yr. However, this seepage would mix with ambient groundwater and ARD would be fully attenuated within the calcareous Bozeman Formation (EIS, Appendix J).

Seepage Quality Analyses of porewater from reclaimed dumps provide the best available estimate of long-term waste rock seepage quality. Detailed data for sulfate concentration of porewater samples is given by Schafer (1995) in GSM's 1995 Hard Rock Mining Permit Application. Based on this data, sulfate concentration in reclaimed dumps vary from 26,300 to 37,500 mg/L. From this data, the EIS (Appendix J) assumes an average sulfate

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concentration of 30,000 mg/L in porewater from reclaimed dumps. For purposes of assessing potential treatment requirements, a sulfate concentration of 30,000 mg/L is also assumed. Data on metal concentrations in porewater is summarized in Table 2 and further discussed in EIS Appendix B that addresses regulatory compliance issues.

Contingencies Water quality impacts beyond the proposed mixing zone (EIS Appendix B) from the East Waste Rock Dump have a very low likelihood of occurring due to the significant neutralization potential that exists in the unsaturated zone and Bozeman Unit. The mixing cell model predicts that treatment will not be required for the East Waste Rock Dump seepage since full chemical neutralization of ARD seepage will occur within the Bozeman Unit between 2,200 and 4,400 feet from the toe of the dump. Water quality will be monitored in downgradient wells to confirm that water quality trends are within the predicted range of concentrations. For purposes of assessing potential treatment contingencies, GSM examined the need for some localized capture of groundwater. Because of the neutralization potential of the Bozeman, there should not be a need for widespread groundwater interception. Capture wells would be used to control the migration of contaminated groundwater if monitoring and subsequent investigation (Section 4.0) indicated preferential transport along discrete flow paths.

Captured seepage would be treated in the water treatment plant prior to discharge. Contingency treatment plans provide for treatment of 25 gpm of groundwater capture from the East Waste Rock Dumps. This is approximately 20% of the predicted flux through the Bozeman beneath the East Waste Rock Dump area (EIS, Appendix L). East Waste Rock Dump porewater water quality is assumed for estimating treatment requirements, however this is a worse case assumption since actual water quality will reflect neutralization in the unsaturated zone and dilution in the regional groundwater system.

TABLE 2. SUMMARY OF WASTE ROCK POREWATER METAL CONCENTRATIONS (mg/L)

Site	Depth (feet)	SO4	As	Cd	Cu	Cr	Fe	Pb	Mn	Ni	Se	Zn
SM2	5	1390	0.006	0.0024	4.59	1.06	4.59	<0.003	0.931	0.2	0.002	0.33
SM3	10	2020	<0.003	0.066	5.97	0.053	2.15	<0.003	31.5	1.09	<0.001	3.55
SM6	10	13600	1.47	0.136	18.3	1.27	2470	<0.003	11.1	3.63	0.046	7.6
SM1	10	14300	0.017	<0.0001	1.51	0.048	267	<0.003	2.07	0.79	0.001	0.58
SM2	40	80500	0.033	0.242	86	0.168	66.2	<0.003	19	3.03	<0.001	27.7
MEAN		7828	0.498	0.088	7.59	0.608	686	<0.003	11.4	1.48	0.016	8.0
GEOMEAN		8484	0.047	0.048	9.18	0.225	53	<0.003	6.629	1.08	0.005	2.7

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2.5 WEST WASTE ROCK DUMP

West Waste Rock Dump Seepage Estimates As previously mentioned, excavation of waste rock dumps during 1994 ground movement and dump moisture investigations indicate that the waste rock dumps at GSM are not discharging to groundwater. Modeling predictions for the West Waste Rock Dumps suggest that seepage to groundwater may not occur for several decades or even centuries (EIS, Appendix J). In theory, seepage from the reclaimed dumps would eventually approach expected infiltration rates that total approximately 14 gpm from the entire West Dump Complex. Unlike the east side of Bull Mountain, the bedrock aquifer on the west side appears to contain negligible calcite with which to attenuate acidity or metals. As a result, GSM has proposed groundwater capture to limit migration of seepage. Analyses presented in the EIS (Appendix L.) suggest approximately 52 gpm of groundwater could need to be captured. A hydrogeological investigation will be conducted to locate optimal monitoring sites and evaluate capture effectiveness downgradient of the West Waste Rock Dump. Recommendations for the number and location of monitoring and capture wells would be based on the results of this investigation.

The capture system theoretically would consist of several components. A series of toe drains would be placed in existing major drainages at the base of the dumps. Seepage through the waste rock will tend to collect in these drainage areas as a result of the low bulk permeability of the underlying bedrock. Groundwater capture wells also are proposed to intercept seepage that migrates to the underlying groundwater system. Water collected by the toe drains and capture wells (an estimated 52 gpm total) would be routed to the permanent water treatment facility on the east side.

Water Quality Predicted quality of water from the proposed west side capture system is summarized in Table 3 and is based on dump pore water data and ambient water quality from west side monitoring wells.

TABLE 3. PREDICTED WATER QUALITY FROM WEST WASTE ROCK DUMP CAPTURE WELLS

	West Flank			East Flank		
Parameter	Ambient GW Concentration(1) (mg/L)	Dump Seepage Concentration(2) (mg/L)	Predicted Pumpback Well Concentration(3) (mg/L)	Ambient GW Concentration(4) (mg/L)	Dump Seepage Concentration(2) (mg/L)	Predicted Pumpback Well Concentration(3) (mg/L)
sulfate	1011	30000	3646	3710	30000	4962
arsenic	0.007	0.027	0.0088	0.0068	0.027	0.0078
cadmium	0.002	0.0139	0.0031	0.025	0.0139	0.0245
copper	0.01	9.18	0.843	0.106	9.18	0.538
chromium	0.004	0.225	0.0241	0.008	0.225	0.0183
iron	2.34	53.32	6.97	148	53.32	143.49
lead	0.007	0.003	0.0066	0.022	0.003	0.0211
manganese	1.85	6.629	2.28	13.8	6.629	13.46
nickel	0.152	1.08	0.236	2.46	1.08	2.394
selenium	0.002	0.002	0.0020	0.0032	0.002	0.0032
zinc	0.458	2.70	0.662	8.99	2.70	8.690
NO2+NO3	0.169	0.11	0.164	0.098	0.11	0.099

Notes:

(1) Calculated from historic data for wells PW-2, -13, -14, -15, -16, -21, -42, -46, and Arkose Spring.
(2) Calculated from waste rock dump lysimeter data.
(3) Resultant water quality after mixing net dump seepage and ambient groundwater.
(4) Calculated from historic data for wells PW-3, -17, and Stepphan Spring.

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Contingencies for Capture and Treatment of West Waste Rock Dump Seepage The capture wells would be completed in the bedrock aquifer and would target preferential flow paths along major structural features. Previous pit dewatering assessments in the bedrock aquifer by GSM indicate that pumping at relatively modest rates can produce significant drawdown over distances of greater than 500 feet, if the pumping wells are sited with regard to geologic structures. The rate of capture will be a function of permeability of the bedrock fractures. The capture analysis in Appendix L assumes a fracture permeability of 10^{-5}cm/sec over 10% of the area. GSM has provided for higher permeability in their contingency design (10^{-4}cm/sec) which would result in a capture rate of 77 gpm.

3.0 WATER TREATMENT

GSM presently operates a small-scale treatment plant to treat ARD water from pit dewatering. The treated water is then used in the mill process circuit. Under GSM's reclamation plan, a permanent water treatment plant would be designed and constructed just prior to closure to treat any discharge from the pit, waste dump or tailing impoundment areas. The permanent treatment plant would use lime neutralization technology for metals removal and would include components for cyanide removal. A detailed description of the proposed treatment process is presented in Attachment A-1.

The proposed permanent water treatment plant would handle flows from the dewatered pit Tailing Impoundment No. 1 pumpback wells, Tailing Impoundment No. 2 underdrains, and water from the West Waste Rock Dump capture system. Treated water would be discharged through an infiltration basin to the Jefferson alluvial gravels south of Impoundment No. 2. Contingency water treatment requirements have been developed that would accommodate additional flows from the proposed facilities as wells as flows from the East Waste Rock Area. The expected flows, design flows and contingency flows to the treatment system are summarized in Table 4. As indicated, the design and contingency flows are several times higher than anticipated flows under the Proposed Action. The quality of potential feed water to the treatment system is summarized in Table 5, with and without contingency flows.

TABLE 4. SUMMARY OF TREATMENT FLOWS IN WATER MANAGEMENT ANALYSIS

Mine Facility	Expected Flow to Treatment System under Proposed Action	Design Flow used in Proposed Action	Design Flow for Proposed Action w/ Contingencies
Pit Water	**54**	**54**	**65**
No. 1 Impoundment	**0**	**200**	**200**
No. 2 Impoundment	**2**	**10**	**25**
West Side Dumps	**52**	**52**	**77**
East Side Dumps	**0**	**0**	**25**
Total	**108**	**316**	**392**

Notes:

Pit Flows *- Estimated treatment requirements for pit water in the proposed action are from pit water balance model. These estimated flows are believed to be conservative based on current pit hydrology and observed flows. Estimated inflows were increased by 20% to provide contingency design flows. If continued mining shows a change in hydrologic conditions within the pit, treatment requirements and contingency flows will be re-evaluated prior to construction of the proposed treatment plant.*

Impoundment No. 1 *- Once the tailing is completely dewatered, GSM anticipates minimal seepage from the impoundment. For purposes of treatment design, GSM has conservatively estimated a continued need for capture and treatment of 200 gpm of groundwater from the No. 1 Impoundment. Based on the observed trend of declining pumping rates at the No. 1 Impoundment this is considered a very conservative estimate of potential long-term treatment requirements. GSM has proposed additional physical controls, such as interception and diversion of Rattlesnake Drainage groundwater away from tailing materials, as a contingency in the event that additional action is required to facilitate long-term dewatering.*

Impoundment No. 2 *- Estimated seepage through the reclaimed Impoundment No. 2 cap is approximately 2 gpm. GSM has conservatively estimated long-term treatment requirements under the proposed action at 10 gpm. Downgradient pumpback wells will be maintained as a contingency. A total treatment requirement of 25 gpm is assumed under this contingency due to capture of an additional 15 gpm of ambient groundwater flux in the Bozeman Formation.*

West Side Waste Rock Dumps *- A total of 52 gpm of groundwater capture is estimated for the West Side Waste Rock Dumps under the "expected conditions" presented in the EIS. Since this assumes 100% capture efficiency, no additional increase was accounted for in calculating design flows for the Proposed Action. GSM has assumed the predicted upper range flow estimate of 77 gpm (EIS Appendix L) under the contingency design analysis.*

East Side Dumps *- An analysis of neutralization potential of the Bozeman has indicated there should be no need for groundwater capture at the East Side Waste Rock Dumps under the proposed action. Under the contingency analysis GSM has assumed a treatment requirement of 25 gpm due to localized capture along discrete flow paths in the Bozeman.*

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TABLE 5. ESTIMATED TREATMENT PLANT FEEDWATER QUALITY AND QUANTITY

Parameter	Pit Water	No. 1 Impoundment	No. 2 Impoundment	West Side Dumps(1)	East Side Dumps	Summary	
						Proposed Action	**Proposed Action with Contingencies**
Flow (gpm)							
Proposed Action	54	200	10	52	0	**316**	
Proposed Action w/ Contingencies	65	200	25	77	25		**392**
pH	2.7	3.4	2.7	3.3	2.5	**2.8**	**2.9**
sulfate (mg/L)	10240	945	10240	7106	3000	**3042**	**6143**
calcium (mg/L)	408	79	408	186	182	**163**	**182**
magnesium (mg/L)	1199	107	1199	210	399	**345**	**396**
aluminum (mg/L)	292	28	292	72	188	**89**	**107**
arsenic (mg/L)	0.411	0.026	0.411	0.011	0.027	**0.101**	**0.111**
cadmium (mg/L)	0.641	0.039	0.641	0.010	0.014	**0.156**	**0.170**
copper (mg/L)	75.9	5.7	75.9	1.76	9.2	**19**	**21**
chromium (mg/L)	0.009	0.0014	0.009	0.046	0.225	**0.010**	**0.026**
iron (mg/L)	1170	67	1170	47	53.3	**285**	**314**
lead (mg/L)	0.274	0.016	0.274	0.010	0.005	**0.067**	**0.073**
manganese (mg/L)	126	7.9	126.0	5.6	6.6	**31**	**34**
nickel (mg/L)	5.8	0.382	5.800	0.89	1.1	**1.6**	**1.8**
selenium (mg/L)	0.015	0.0022	0.015	0.0023	0.002	**0.0048**	**0.0052**
zinc (mg/L)	90.4	5.6	90.4	2.9	2.7	**22**	**24**
nitrate+nitrite as N (mg/L)	10.9	3.9(2)	10.9(3)	0.14	0.1	**4.70**	**4.53**

Notes:

(1) Includes water from west dump pumpback wells and west dump toe drains.

(2) Assumes 10 gpm impoundment seepage at 40 mg/L NO3-N and 190 gpm Rattlesnake groundwater at 2 mg/L NO3-N.

(3) Assumes no significant CN source for NO3-N due to operational treatment. NO3-N concentration based on pit water source.

The quantity and quality of feedwater to the treatment system will vary over time in response to changing hydrologic and geochemical conditions in the pit, impoundments and waste rock dumps. Anticipated timing of flows is summarized below:

- **Pit Water** - At the close of operations, pit dewatering will cease and the pit will be allowed to fill to the 5050 foot elevation. There should be no discharge to the treatment system from the pit for 20 to 30 years based on the estimated time for the pit pond to reach the 5050 foot elevation (Hydrometrics, 1995). Approximately 54 gpm would be pumped and treated at that time.

- **Waste Rock Dumps** - No seepage is predicted from the waste rock dumps for at least 20 to 70 years based on models presented in the EIS. This reflects the minimum time predicted before sufficient moisture would accumulate in the dumps and produce seepage. An estimated 52 gpm would need to be treated as a result of groundwater capture from West Side Waste Rock Dump.

- **Impoundment No. 1** - It has been conservatively assumed that treatment would be required at closure, but flows are predicted to decrease substantially below the initial 200 gpm estimate over time. Treatment plans assume 10 years of post-mining treatment for cyanide, after which treatment is for metals only.

- **Impoundment No. 2** - Initially, water from the underdrain system will be collected in the secondary containment basins and spray evaporated until the tailings dewater. The conservative long-term flow estimate is 10 gpm from the Impoundment No. 2 underdrain.

Estimated seepage trends indicate little or no ARD treatment demand immediately following closure, since during this period the pit is filling to 5050 foot elevation, seepage from Impoundment No. 2 is being spray evaporated, and waste rock dumps are not yet anticipated to be discharging. The potential for these facilities to generate excess water will increase over time. Immediate treatment of 200 gpm of flow from the No. 1 Impoundment is included

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as a conservative measure at closure. Seepage flows and cyanide concentrations are expected to decrease over time as a result of proposed dewatering activities in this area.

Cyanide treatment is included as a short-term (10 year) treatment contingency should residual cyanide still be present after closure. In addition to treatment contingencies for cyanide, the water treatment analysis also includes contingencies for nitrate removal, if present from cyanide breakdown. However, this nitrogen source would be expected to decrease over time.

As indicated in Table 4, concentrations of nitrate-nitrogen in feedwater should be below the 7.5 mg/L non-degradation limit for nitrate-nitrogen in groundwater under assumed flow conditions. The actual concentration of nitrogen is likely to vary depending on the relative contribution from each source. The contingency for nitrate treatment is provided in the event that initial flows to the treatment system are derived from a high concentration source.

4.0 MONITORING AND IMPLEMENTATION OF MITIGATION

GSM has monitored groundwater and surface water conditions in and adjacent to the mine site since operations began, and will continue to do so after mining ceases. The current monitoring plan (Attachment A-2) was developed jointly with MDEQ and BLM over the past fifteen years of operations. It incorporates the most current knowledge of hydrogeological conditions and considers past and present mining activities. The monitoring plan targets key monitoring sites adjacent to mine facilities, emphasizes seasonal monitoring, and uses indicator parameters to detect potential water quality changes.

4.1 MONITORING OBJECTIVES

Water resources monitoring at GSM has the following objectives:

- Enable rapid detection of potential changes in hydrologic conditions.
- Monitor key locations that represent specific hydrostratigraphic units upgradient and downgradient of mine facilities.
- Obtain data to support mine engineering and facility design.
- Provide a long-term project data base to document hydrologic conditions through post reclamation.
- Document compliance with state and federal water quality laws.

The general categories of sites monitored consist of sites adjacent to tailing impoundments, sites adjacent to pit and waste rock dumps, and off-site and background area sites (which include private residences).

4.1.1 Monitoring Schedule and Monitoring Sites

The GSM monitoring schedule (Attachment A-2) includes parameters that were consistently detected in previous years as well as indicator parameters that, although not necessarily present in some areas, could be used to detect changing water chemistry. For instance, selected sites adjacent to tailing impoundments are monitored for indicator trace metals to determine if ARD may be developing as tailing material drains and becomes oxidized.

GSM also is seeking authorization from MDEQ to allow for groundwater mixing of potential long-term sources of discharge associated with mine facilities (EIS Appendix B). Once mixing zones are approved, the monitoring schedule will be revised to include the expanded parameter list for the compliance sites along the mixing zone boundaries.

Like the parameter list, the monitoring frequency is based on previous monitoring results. For the majority of sites at GSM, quarterly monitoring has been determined to be the most appropriate interval to observe seasonal variations in ambient conditions. Less frequent monitoring is performed in background areas, and more frequent monitoring is performed adjacent to the tailing impoundments and at key locations adjacent to waste rock dumps and the open pit to provide for early detection and mitigation.

The water resources monitoring sites (Figures A1 and A2 in Attachment A-2) were selected to represent particular hydrologic units and provide good areal coverage across the entire project area. These sites also have either a good historical data base, or are located in key hydrologic locations adjacent to mine facilities. The selected groundwater monitoring wells are screened at different depths below the land surface to ensure adequate coverage of hydrostratigraphic intervals and groundwater flow paths within the general region of the mine. The GSM project area is shown in relation to the regional topographic/hydrologic setting on Figures A3 and A4 in Attachment A-2. The regional drainage systems include Conrow Creek, Sheep Rock Draw, St. Paul Gulch, and the Jefferson Slough/Jefferson River.

4.1.2 Proposed Expansion of Monitoring System

GSM presently monitors over 120 water resources sites. Approximately 18 of these are groundwater monitoring wells directly adjacent to and downgradient of waste rock areas. The wells are completed at various depths within the bedrock and Bozeman hydrostratigraphic units, and in alluvium, colluvium on the east and west sides of Bull Mountain. Upon approval of GSM's proposed amendment, GSM intends to construct approximately 6 new monitoring wells along the downgradient perimeter of existing and expanded waste rock areas. The tentative locations of the proposed monitoring wells are shown on Figures A1 and A2 in Attachment A-2.

The tentative well locations on the west side of bull Mountain are based on the presence of geologic structures identified by GSM. The exact number and location of the new monitoring wells will be based on a hydrogeologic investigation of the bedrock unit downgradient of waste rock areas. The new wells on both east and west sides of Bull Mountain will be constructed according to Montana Board of Water Well Contractors specifications and will consist of 4-inch diameter PVC pipe with a perforated interval between 40 and 100 feet long to ensure that a sufficient aquifer thickness is monitored.

GSM also intends to construct additional monitoring wells in conjunction with MDEQ authorization of groundwater mixing zones (EIS appendix B). The exact number and locations of the mixing zone compliance wells are uncertain at this time (pending mixing zone approval), but would likely consist of 6 to 8 new wells along the east, south and west boundaries of the proposed mixing zones.

4.1.3 Long-Term Monitoring

Monitoring will be conducted as per the schedule in Attachment A-2 during operations and after mining ceases. The long-term, post reclamation monitoring would continue until such time that it is no longer required by the agencies. With agency concurrence, the long-term monitoring would likely be at a reduced frequency, only performed at key sites adjacent to reclaimed mine facilities and for mixing zone compliance, and include site-specific, key indicator parameters that reflect potential discharge sources (e.g. ARD, tailing seepage, treatment plant effluent).

4.1.4 Data Analysis and Reporting

GSM internally reviews monitoring results monthly by trend analysis that compares the most recent water quality data with data collected over the period of record. All monitoring data are presented with narrative discussion of data interpretation in GSM's Annual Report to MDEQ and BLM. Monitoring, data analysis, and annual reporting would continue through post-reclamation until they are no longer required by the agencies.

GSM has and will continue to promptly notify the agencies should the trend analysis detect a change in water quality due to GSM's operations. The following steps outline the procedure that will be taken during operations and post-reclamation if GSM's monthly data trend analysis identifies an anomalous result:

1. Resample - The site(s) showing a change in water quality will be immediately resampled if the anomalous result is outside of the normal range of ambient variation.

2. Increase Monitoring Frequency - Depending on the observed change in water quality, the sampling frequency of the site(s) showing the change may be increased to weekly, monthly, or bi-monthly to monitor the site more closely and document the change in trend.
3. Verification of Change in Trend - GSM will perform statistical analysis (using a MDEQ-approved methodology) of the data set for the site in question to verify and determine the magnitude of change in water quality trend.
4. Agency Notification and Consultation - Upon verification, GSM will immediately notify MDEQ and BLM if the change in water quality condition is likely to exceed applicable regulatory requirements and trigger implementation of water management mitigation measures. GSM will consult with the agencies to determine the appropriate course of action to identify and/or mitigate the source of changing water quality.

4.2 IMPLEMENTATION OF MITIGATION

In consultation with MDEQ and BLM, GSM will begin implementation of the appropriate water management component and/or contingency measure as described in Section 2 of this water management plan for the area(s) showing verified changes in water quality trend. Depending on the area that is showing the change, either groundwater interception/pumping to a water treatment facility or use of natural attenuation within a designated mixing zone will be the mitigation approach. The change (action level) that would trigger mitigation as described in Section 2 of this water management plan is as follows:

Open Pit - A trend of increasing concentrations in constituents outside of the normal range of ambient water quality from pit-area wells will be used as the basis to determine if ARD is migrating away from the dewatered pit. Pit area groundwater migration also could be verified by changes in hydraulic gradient (potentiometric surface) surrounding the pit. Mitigation through increased dewatering will be implemented if the trend indicates a likelihood for noncompliance with regulatory requirements (e.g. nondegradation rule).

Impoundment No. 1 - Trend analysis showing either no change or an increase in the present concentrations of tailing constituents (e.g. cyanide, nitrate, metals, etc.) in groundwater from pumpback wells and monitoring wells adjacent to the impoundment area will be used as the basis for continued pumpback well operation.

Impoundment No. 2 - A trend of increasing concentrations of constituents in groundwater from wells adjacent to Impoundment No. 2 that show leakage is occurring from the lined facility will be used as the basis to implement groundwater interception/pumpback.

East Waste Rock Complex - Groundwater will be monitored from existing and proposed wells along the perimeter of the east waste rock complex (including the Buttress Dump), along the outer boundary of an approved mixing zone, and at points in between (along the approximate groundwater flow path). Contingency mitigation measures (seepage collection and treatment) will be implemented if ARD appears on the land surfaces, at the dump toe, or if groundwater constituents from wells along the dump perimeter and midway to the boundary of a designated mixing zone exceed the theoretical, maximum predicted concentrations of ARD (e.g. sulfate, metals, etc.) by 20% of the worst case (based on distance from source) as described in EIS Appendix J. The 20% exceedance will whether the model in EIS Appendix J may have underestimated the potential ARD impact, but allows for sufficient time to implement mitigation and prevent impacts outside of the mixing zone (EIS Appendix B).

West Waste Rock Complex - Like the east waste rock complex, groundwater will be monitored from existing and proposed wells along the perimeter of the west waste rock complex (both east and west flanks), along the outer boundary of an approved mixing zone, and at points in between (along the approximate groundwater flow path). Mitigation measures (seepage collection and treatment) will be implemented if ARD appears on the land surface at the dump toe, or if groundwater constituents from wells along the dump perimeter and midway to the boundary of a designated mixing zone exceed the theoretical, maximum predicted concentrations of ARD (e.g. sulfate, metals, etc.) by 20% of the expected case as described in EIS Appendix J. Again, the 20% criterion is used to verify potential exceedances and still enable compliance with downgradient regulatory requirements.

Water Treatment Plant Discharge - Treatment plant effluent will be monitored to ensure treatment requirements are being met. Groundwater also will be monitored in wells along the perimeter of the treatment plant discharge pond, along the outer boundary of an approved mixing zone, and at points in between (along the approximate groundwater flow path). Mitigation measures for the treatment system will be implemented if changes in groundwater quality (e.g. increases in metals, nitrate, etc.) from any well or, the concentrations in the effluent itself, indicate that mixing will not achieve regulatory compliance beyond the designated mixing zone boundary.

In some instances it may be more appropriate to determine if a site-specific approach to mitigation can be used to address a change in water quality, rather than immediately begin implementation of a predefined water management component. This is particularly true in the west and east waste rock dump areas, where the heterogeneity of the waste rock material and underlying hydrostratigraphy could result in a localized source of discharge. GSM may seek a variance from the water management approach described above and, with agency approval, develop a site-specific plan in consort with the appropriate regulatory personnel. A site-specific plan could include the following:

1. Identify Source - The surface and subsurface hydrogeologic conditions in the area where the changing water quality is occurring would be investigated to identify the source. This work could include test boring and soil sampling, constructing new monitoring wells for water sampling and aquifer testing, and hydrogeologic mapping to verify localized groundwater flow paths.
2. Assess Potential Impacts - A fate and transport analysis would be conducted to assess the extent of impact to water quality, the potential risk to beneficial uses, and the potential for noncompliance with regulatory requirements. The

results of the analysis would then be used to determine the additional actions needed.

3. Source Control - Appropriate measures to control the source from the land surface would be taken. These could include changing the current land use practice, placing additional cover/capping materials over the source, and/or controlling surface water or groundwater recharge entering the source area.
4. Mixing zone Modification - GSM and DEQ would determine if a modification can be made to the designated mixing zone to address the parameter(s) of concern.
5. Groundwater Control - Site-specific groundwater control systems would be constructed that could include interception wells and/or collection drains.
6. Monitor - Monitoring would continue according to a revised plan to verify whether conditions have stabilized or improved.

5.0 ESTIMATED COSTS

Costs were developed for monitoring, collection and treatment of seepage water under the proposed action based on long-term water management considerations described in Section 2. Capital costs, equipment replacement costs, and operating and maintenance costs are summarized in Table 6. In developing these costs, GSM has included all direct costs for materials and installation and assumed administration and oversight by GSM. Capital costs, equipment replacement costs, and operating and maintenance costs are summarized in Table 7. These costs are considered as general estimates and are based on published engineering design cost books, GSM construction experience and best professional judgment. A detailed breakdown of treatment costs is provided in the water treatment system design report in Attachment 1 to this appendix.

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TABLE 6. ESTIMATED COSTS FOR CONSTRUCTION OF WATER HANDLING FACILITIES

FACILITY	COST		DESCRIPTION
West Side Waste Rock Dump	$	349,274	Construction of 8 toe drains & 8 captures wells, includes all direct costs for excavation, gravel placement & backfill, well installation, sumps, pumps, electrical (poles, conductors, transformers, etc.), roads (cut & fill, culverts, topping), and pipeline installation (15,900 feet of 4"HPDE & 4,050 feet of 2" HPDE).
East Side Waste Rock Dump (Contingency)	$	127,247	Construction of 8 capture wells and 8 monitoring wells, includes: all direct costs for well installation and instrumentation, electrical (poles, conductors, transformers, etc.), and pipeline installation (17,650 ft of 2"HPDE). [CONTINGENCY ONLY - NO NEED FOR CAPTURE IS PREDICTED UNDER PROPOSED ACTION]
Mine Pit	$	78,785	Installation of Barge Mounted Pump System including barge and pumps, walkway, electrical (poles, conductors, transformers, hook-up) and pipline installation (4900 ft of 6" HPDE).
Impoundment No.2	$	18,702	Wells and electricity in are place, costs include installation of submerisible pumps and 1500 feet of HPDE pipeline.
Impoundment No.1	$	-	Wells, electricity, pumps and pipeline are in place.
Totals	$	446,761	Proposed Action
	$	574,008	Proposed Action w/East Dump Pumpback Contingency

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TABLE 7 SUMMUARY OF ESTIMATED COSTS FOR LONG-TERM WATER MANAGEMENT

Facility	Construction Costs	O&M	Anticipated Time until Start-Up (post-closure)	Replacement Costs				
				5 yr	10 yr	20 yr	30 yr	60 yr
West Side Waste Rock Dump	$ 349,274	$ 21,840	50 to 350 yrs	$ 35,258	$ 14,820	$ 20,400	$ 129,698	$ 79,683
East Side Waste Rock Dump (Contingency)	$ 127,247	$ 10,920	Contingency Only	$ 13,840	$ 12,355	$ 15,600	$ 63,292	—
Mine Pit	$ 78,785	$ 24,629	20 to 30 yrs	—	$ 19,690	$ 16,050	$ 32,748	$ 54,696
Impoundment No.2	$ 18,702	$ 3,780	5 to 10 yrs	$ 10,380	—	$ 4,950	$ 10,068	$ 8,322
Impoundment No.1		$ 46,764	—	$ 38,060	—	$ 17,250	$ 32,644	$ 41,665
Totals	$ 574,008	$ 107,933	—	$ 97,538	$ 144,403	$ 218,653	$ 487,103	$ 671,459

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ATTACHMENT A-1

DESIGN AND ESTIMATED COSTS FOR
WATER TREATMENT PLANT AT
GOLDEN SUNLIGHT MINES, INC.

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DESIGN AND ESTIMATED COSTS FOR WATER TREATMENT PLANT AT GOLDEN SUNLIGHT MINES, INC.

Prepared for:

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August 1997

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DESIGN AND ESTIMATED COSTS FOR WATER TREATMENT PLANT AT GOLDEN SUNLIGHT MINES, INC.

1. INTRODUCTION

Golden Sunlight Mines (GSM) may require a water treatment system to remove metals and TDS from potential long-term sources of mine discharge. GSM engineers developed a preliminary design and cost evaluation for a lime precipitation treatment plant (Storey 1992). Hydrometrics reviewed the preliminary design and recommended several modifications to improve treatment effectiveness, reliability and overall long term costs of ownership (Hydrometrics 1995a, 1996).

This report updates the earlier design and incorporates additional information that reflects GSM's best estimate of its long-term water treatment needs. Specifically, this report addresses:

- Updated flow and water quality information for water requiring treatment in the proposed plant.
- Additional sources of water requiring treatment.
- Contingency treatment measures and costs to account for uncertainties associated with treatment effectiveness and future water quality and flows.

The major differences between this report and the previous reports (Hydrometrics 1995a, 1996) are:

- Addition of potential seepage from the west waste rock complex requiring treatment for TDS and metals.
- Deletion of assumed treatment of Tailings Impoundment No. 1 water for cyanide. Instead, cyanide treatment is added as a contingency.

- Inclusion of contingency treatment measures to handle potential seepage from the east waste rock complex.

- Inclusion of contingency treatment measures for nitrate removal (Impoundment No. 1 water only).

This report describes:

1. Untreated flow and water quality from potential long-term discharge sources

2. Preliminary effluent limits based on nondegradation rules and ambient groundwater quality

3. An evaluation of proposed water treatment methods and design considering:

    a) The treatment method used to meet the proposed action plan

    b) The ability of the proposed treatment plant to meet effluent limits

4. An evaluation of contingency treatment measures, which may include testing of passive treatment systems.

5. Estimated capital and operating costs for meeting action plan requirements and incorporating, if necessary, contingency treatment measures.

2. UNTREATED WATER FLOW AND QUALITY

According to the GSM's best estimates, three sources of water will likely require perpetual treatment. They include pit water, seepage from Tailings Impoundment No. 2 and seepage from the west waste rock complex. In general, these sources can be characterized as typical acid rock drainage (ARD) having a pH of 2 to 3 and relatively high concentrations of metals.

In addition to these sources, other sources of water may also require treatment. They include seepage water from Tailings Impoundment No. 1 and the east waste rock complex. Specific measures will be implemented to eliminate flow from these sources. However, as a conservative measure, GSM assumes there will be a long-term need to treat ARD discharge associated with the south and east flank pumpback well systems adjacent to Impoundment No. 1.

In addition, since cyanide concentrations in Impoundment No. 1 will likely decrease to below anticipated discharge limits by the time the treatment plant becomes operational (due to natural degradation), cyanide treatment is not anticipated. However, contingency treatment plans and costs were included in this report, since the effectiveness of source reduction measures and natural degradation of cyanide will not be known until later.

Table 2-1 summarizes the anticipated and contingency treatment plant influent flows and water quality.

TABLE 2-1. ESTIMATED TREATMENT PLANT FEEDWATER QUALITY

Parameter	Pit Water	No. 1 Impoundment	No. 2 Impoundment	West Side Waste Rock[1]	East Side Waste Rock	Summary	
						Proposed Action	Proposed Action with Contingencies
Flow (gpm)							
Proposed Action	54	200	10	52	0	316	
Proposed Action w/ Contingencies	65	200	25	77	25		392
pH	2.7	3.4	2.7	3.3	2.5	2.8	2.9
sulfate (mg/L)	10240	945	10240	7108	30000	3842	6143
calcium (mg/L)	408	79	408	186	182	163	182
magnesium (mg/L)	1199	107	1199	210	399	345	396
aluminum (mg/L)	292	28	292	72	188	89	107
arsenic (mg/L)	0.411	0.026	0.411	0.011	0.027	0.108	0.111
cadmium (mg/L)	0.641	0.039	0.641	0.010	0.014	0.156	0.170
copper (mg/L)	75.9	5.7	75.9	1.76	9.2	19	21
chromium (mg/L)	0.009	0.0014	0.009	0.046	0.225	0.010	0.026
iron (mg/L)	1170	63	1170	47	53.3	285	314
lead (mg/L)	0.274	0.016	0.274	0.010	0.003	0.067	0.073
manganese (mg/L)	126	7.9	126.0	5.6	6.6	31	34
nickel (mg/L)	5.8	0.382	5.800	0.89	1.1	1.6	1.8
selenium (mg/L)	0.015	0.0022	0.015	0.0023	0.002	0.0040	0.0052
zinc (mg/L)	90.4	5.6	90.4	2.9	2.7	22	24
nitrate+nitrite as N (mg/L)	10.9	3.9(2)	10.9(3)	0.14	0.1	4.70	4.53

Notes:

(1) Includes water from west dump pumpback wells and west dump toe drains.

(2) Assumes 10 gpm impoundment seepage at 40 mg/L NO_3-N and 190 gpm Rattlesnake groundwater at 2 mg/L NO_3-N.

(3) Assumes no significant CN^- source for NO_3-N due to operational treatment. NO_3-N concentration based on pit water source.

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3. PRELIMINARY EFFLUENT DISCHARGE LIMITS

The goal of the treatment plant is to produce effluent quality that is equal to, or better than the receiving ambient water quality. GSM is submitting an application to DEQ for authorization of groundwater mixing zones for potential long-term mine discharges (EIS Appendix B). The treatment plant effluent discharge limits are designed to comply with the Montana nondegradation rule beyond the designated mixing zone for the treatment plant infiltration pond.

For purposes of this report, we have assumed that ambient water quality levels for metals (Table 3-1) must be met. A detailed explanation of this ambient water quality is available in the mixing zone report (EIS Appendix B).

TABLE 3-1 TARGET EFFLUENT WATER QUALITY

Parameter	Mean (mg/L)	Geometric Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)
pH	7.2	7.1	6.3	7.8
TDS	1935	1549	530	3100
sulfate	868	648	190	1510
NO_2+NO_3	41	23.6	2.46	80
aluminum	0.1	0.1	0.1	0.1
antimony	nd	nd	nd	nd
arsenic	0.005	0.005	0.005	0.005
barium	0.1	0.1	0.1	0.1
beryllium	nd	nd	nd	nd
cadmium	0.001	0.001	0.001	0.001
copper	0.02	0.018	0.01	0.03
chromium	nd	nd	nd	nd
iron	0.03	0.03	0.03	0.03
lead	0.01	0.01	0.01	0.01
manganese	0.013	0.012	0.01	0.02
mercury	nd	nd	nd	nd
nickel	nd	nd	nd	nd
selenium	nd	nd	nd	nd
silver	0.005	0.005	0.005	0.005
thallium	nd	nd	nd	nd
zinc	0.07	0.069	0.08	0.06

NOTES:

All concentrations in mg/L.

Concentrations calculated from most recent data for four wells:

Well	Sample Date
OW-2	(3/12/97)
OW-3	(3/12/97)
OW-5	(9/17/86)
OW-7	(12/26/89)

nd = no data for this parameter.

Below detect values replaced by the detection limit for calculations.

4. TREATMENT APPROACH AND PLANT DESIGN

Ideal water treatment facilities employ technologies that are simple, have the fewest possible treatment steps, are cost-effective, produce high-quality effluent and are consistently reliable with few operational problems. GSM's primary treatment objectives are to achieve regulatory compliance requirements, which include treatment for metals and total dissolved solids (TDS). A number of treatment options were considered by GSM and its consultants for removal of TDS and metals from commingled site waters, including chemical precipitation, ion exchange and reverse osmosis. Based on feed water quality, process complexity and site-specific conditions, chemical precipitation was selected as the most cost-effective and reliable technology for meeting action plan requirements. This process would also incorporate a proven methodology for producing a "high density sludge" (about 20 percent solids versus 3 to 6 percent solids produced in a conventional lime precipitation process). Sludge produced from this process would then be dewatered and landfilled on-site.

In addition, several add-on treatment steps were selected as contingency measures for treatment of cyanide and nitrate should treatment for either of these parameters eventually become necessary.

Golden Sunlight has selected this treatment approach and plant design based on conservative, proven methods. Low-maintenance passive treatment systems, which are capable of neutralizing ARD and removing metals, cyanide, nitrate and sulfate, are also becoming widely used. Because of their aesthetic and cost advantages, GSM may also consider pilot-scale testing this type of treatment system.

4.1 TREATMENT TO MEET GSM PROPOSED ACTION PLAN

The primary design characteristics associated with pit water and future tailings water quality at the Golden Sunlight Mine site are the presence of acidity (pH < 3.0) and high concentrations of TDS (mostly sulfate) and metals. In addition, the high concentration of dissolved ferrous iron in pit water was considered in the water treatment plant design.

A schematic diagram of the entire treatment process is presented in Figure 4-1. The process consists of:

- Hydroxide precipitation of metals at pH 10.5
- Air oxidation to convert ferrous iron to ferric iron
- Flocculation and clarification
- Sludge dewatering and disposal
- Acidification of effluent to meet discharge pH limit (pH 6 to 9)
- Discharge to an infiltration pond
- Dewatering of sludge in a filter press for on-site landfill disposal.

Treatment objectives are to produce effluent quality equal to, or better than receiving ambient groundwater quality (Table 3-1). The following section describes each of these treatment steps and anticipated effluent water quality.

4.1.1 Hydroxide Precipitation and Air Oxidation

Hydroxide precipitation is a common method of removing metals from wastewater. It was chosen because it is normally effective, and relatively low in capital and operating costs. Pit water, with a pH between 2 and 3, will be supplied to the neutralization tank directly from a pump station located at the pit (Figure 4-1). The pH of the neutralization tank will be maintained at 10.5 using a pH sensor and feedback controller to adjust the flow of lime slurry to the alkalization tank. Alkalization tank slurry will overflow into the neutralization tank. Compressed air will also be supplied to the neutralization tank to oxidize iron in the process water. Oxidation of iron from the ferrous form to the ferric form will stabilize the sludge for long-term storage in the landfill. The addition of air to this tank at pH 10.5 should also strip any ammonia that may still be present in the tailings water. The neutralization tank will be baffled and agitated.

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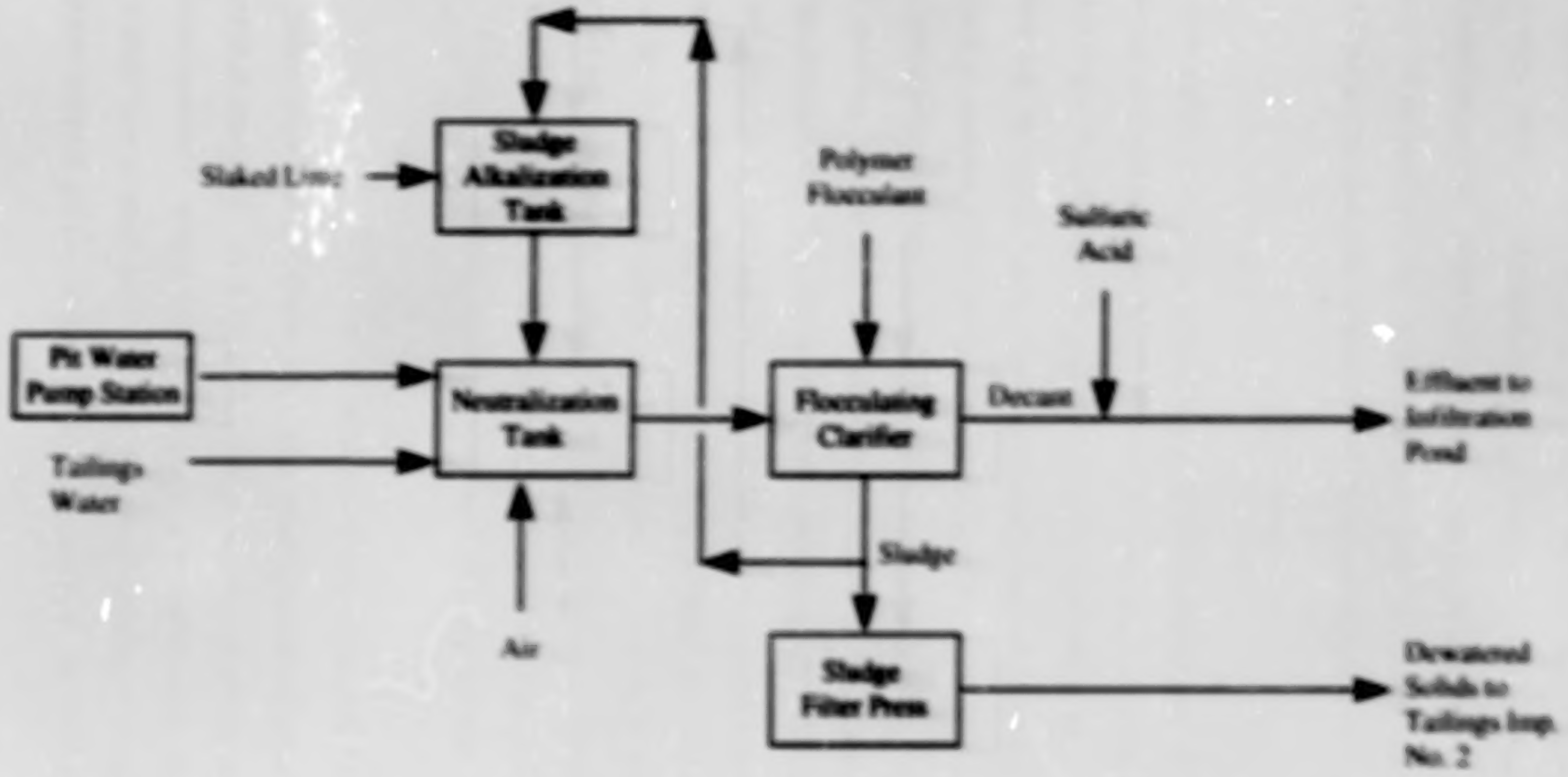

GOLDEN SUNLIGHT MINE

PROPOSED WATER TREATMENT PLANT TO MEET ACTION PLAN

FIGURE 4-1

Hydrometrics, Inc.

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Lime slurry will be automatically prepared in a lime slaking system. The lime system consists of a lime storage silo and feeder, lime slaking system and slurry pump. Dry lime will be pneumatically conveyed from trucks into the storage silo. A rotary valve will supply lime from the silo into the lime solution tank, where a lime slurry will be prepared by mixing the dry lime with service water. A pump will continually recycle lime slurry (slaked lime) through a piping loop, with portions drawn off to the alkalization tank as required to maintain the pH.

Conventional hydroxide precipitation processes typically produce a sludge which is very difficult to settle and dewater. The bulk of the metals in the pit water will be removed by hydroxide precipitation using the High Density Sludge (HDS) process or a process similar to it. The HDS process is a modified precipitation process which changes the physical nature of the sludge and makes it much easier to dewater. In the HDS process, a portion of the precipitated solids is recycled to a separate tank (the alkalization tank) where the solids react with lime. In this tank, lime is adsorbed onto the recycled sludge particles to produce alkalized sludge. Alkalized sludge is then used to raise the pH in the neutralization tank to precipitate metals. When process water and alkalized sludge react, lime coats the surface of the particles so the precipitate tends to grow on an existing particle rather than nucleating a new one. This results in growth of larger particles, which settle better and are easier to dewater than conventional metal hydroxide sludge. Another advantage of the HDS process is that it minimizes scaling of gypsum (calcium sulfate), which could plug process equipment such as piping, filters, and pumps as well as the infiltration ponds.

4.1.2 Flocculation, Clarification and Discharge

The well mixed slurry in the neutralization tank then overflows to a flocculating clarifier to remove metal-bearing solids by simple settling (Figure 4-1). Polymer flocculant will be metered to the clarifier flocculation tank using a metering pump. Polymer solution will be automatically prepared in a polymer make-up system. This system will consist of a screw feeder and blower to feed dry polymer from a bin into a mixing ("make-down") tank for polymer solution preparation. After the polymer solution has "aged," the solution will be gravimetrically transferred to a polymer solution feed tank.

Decant from the clarifier will then flow by gravity to a infiltration pond for discharge (Figure 4-1). The pH of the decant, about 10.5, will be adjusted downward through addition of sulfuric acid as it overflows the clarifier. Acid will be supplied from a storage tank through a metering pump, using a pH sensor and feedback controller. Settled sludge will be withdrawn from the bottom of the clarifier through a sludge recycle pump. A portion of this sludge will be recycled to the alkalization tank, with the remainder sent to a sludge storage tank.

4.1.3 Sludge Dewatering and Disposal

Sludge will be pumped periodically from the storage tank to a recessed-plate filter press for sludge compression and dewatering. Filtrate from the press will be recycled to the neutralization tank, and solids will be collected and sent to an on-site landfill.

Dewatered sludge will be transported by truck or as a slurry by pipeline from the treatment plant to a landfill site within Tailings Impoundment #2. Disposal of sludge at this location is desired because the impoundment is equipped with a liner, seepage collection system and a monitoring well network. Since the impoundment will already be capped before the treatment plant is operational, it will be necessary to first remove the cap to landfill the dewatered sludge and then recap the disturbed area with the same material. Sludge disposal is described in Appendix C of GSM's EIS.

4.1.4 Automated Process Control

An automated process control software package will be installed to provide consistent, long-term performance and prevent violation of effluent discharge limits during inevitable process upsets. This centralized process control package will "tie together" all instrumentation, motors and automated valves to allow consistent start-up and shut-down routines, and provide continuous monitoring of critical process parameters. In the event of equipment failure or operation outside of the optimum control limits, the process would be automatically shut down to prevent effluent quality from exceeding discharge limits. This level of process control is routine for permanent treatment plants that are required to continuously produce effluent quality within specified regulatory limits.

4.1.5 Predicted Quality of Treated ARD Water

Predicted water quality from GSM's proposed treatment plant, and a summary of resultant water quality of treated pit waters from bench-scale testing and GSM's operating pilot plant, are shown in Table 4-1. In general, the highest treatment effectiveness (i.e. lowest metals, TDS and sulfate concentrations) was achieved at the design treatment pH of 10.5. Resultant water quality from all testing met Best Available Technology (BAT) requirements. Although good metals removal was achieved at all pH values above 7.5, treatment did not result in sulfate and TDS removal unless a final treatment pH value of 9 or greater was attained. Additional metals, TDS and sulfate removal are realized at higher final pH values of 10 or 10.5.

4.2 CONTINGENCY TREATMENT MEASURES

Contingency treatment measures for cyanide and nitrate were developed to address uncertainties associated with sources and quality of water requiring treatment in the future.

4.2.1 Cyanide Destruction

Short-term treatment for cyanide present in Impoundment No. 1 pumpback well water may be required as a contingency measure. Cyanide will not be present in Tailings Impoundment No. 2 water since tailings will be treated for cyanide before they are discharged into the impoundment, and tailing water draining from the impoundment at closure will be spray-evaporated over the impoundment surface.

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TABLE 4-1. PREDICTED EFFLUENT WATER QUALITY

All values are in mg/L.

	Treated Pit Water				
Parameter	**pH 7.5⁽¹⁾**	**pH 8⁽²⁾**	**pH 9⁽²⁾**	**pH 10⁽²⁾**	**pH 10.5⁽²⁾**
TDS	7,400	4,485	3,970	1,200	1,200
Calcium	599	497	778	451	732
Magnesium	1060	1423	996	556	153
Sodium	64	71.4	70.5	69.6	70.5
Potassium	NA	NA	NA	NA	NA
Sulfate	3842 (4)	3402 (5)	2200 (5)	2200 (5)	2200 (5)
Nitrate/Nitrite (N)	5.74 (3)	5.74 (3)	5.74 (3)	5.74 (3)	5.74 (3)
Aluminum	<0.1	0.379	0.144	<0.05	<0.05
Arsenic	<0.005	<0.001	0.002	0.001	0.001
Cadmium	<0.028	0.005	0.001	<0.001	<0.001
Chromium	NA	0.021	0.024	0.021	0.016
Copper	0.03	0.019	0.026	0.008	0.007
Iron	<0.03	<0.05	<0.05	<0.05	<0.05
Lead	<0.02	0.003	0.004	0.001	<0.001
Manganese	7.79	0.584	<0.05	<0.05	<0.05
Mercury	NA	NA	NA	NA	NA
Nickel	NA	0.022	<0.001	<0.001	<0.001
Selenium	NA	NA	NA	NA	NA
Silver	NA	NA	NA	NA	NA
Zinc	0.74	<0.05	<0.05	<0.05	<0.05

NA = Not Available

Notes:

(1) Source: August 1993 Stage II Pit treated water quality from September 29, 1993 Golden Sunlight memo from S. Gallagher to F. Fraser.

(2) Source: Results of September 1993 lab test.

(3) Predicted nitrate + nitrite concentrations based on flows and quality associated with proposed action (Table 2-1), assuming no nitrate removal in treatment plant.

(4) From Table 2-1.

(5) Based on maximum solubility of calcium sulfate after lime precipitation.

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The process selected for cyanide destruction involves addition of hydrogen peroxide to oxidize cyanide to cyanate. Since tailing water contains a very low solids concentration, the amount of hydrogen peroxide needed for cyanide oxidation is estimated to be between two and four times the stoichiometric requirement (Degussa Corporation 1996). The optimum peroxide dose and corresponding total cyanide concentration in the effluent need to be determined in bench-scale tests.

If cyanide removal is required, Impoundment No. 1 water would be supplied to the first cyanide reactor directly from the pumpback system located at the tailing impoundment (Figure 4-2). Two cyanide reactors are included in the process to provide a total residence time of 60 minutes. Hydrogen peroxide (50 percent H_2O_2) will be added to the first and second reactor through separate metering pumps. Hydrogen peroxide will be supplied from a feed tank, which is filled periodically from a bulk truck.

The pH of the tailing water (initially about 8 when cyanide is present) will be raised to between 9 and 10.5. The optimum pH for cyanide destruction will need to be determined in bench-scale tests. Lime addition will be automatically adjusted to maintain a specified treatment pH in the first reactor using a pH sensor and feedback controller. The pH will be monitored in the second reactor, but should remain the same as in the first reactor. Each reactor will be baffled and agitated.

4.2.2 Nitrate Removal

It is not anticipated that treatment will be required for nitrate removal. However, as a contingency, numerous technologies have been developed and are available to remove nitrate from water. Ion exchange (IX) and reverse osmosis (RO) have been successfully used worldwide for over 20 years to remove nitrate and other ions to low concentrations, but their primary disadvantages are high capital and operating costs, and generation of a concentrated waste stream.

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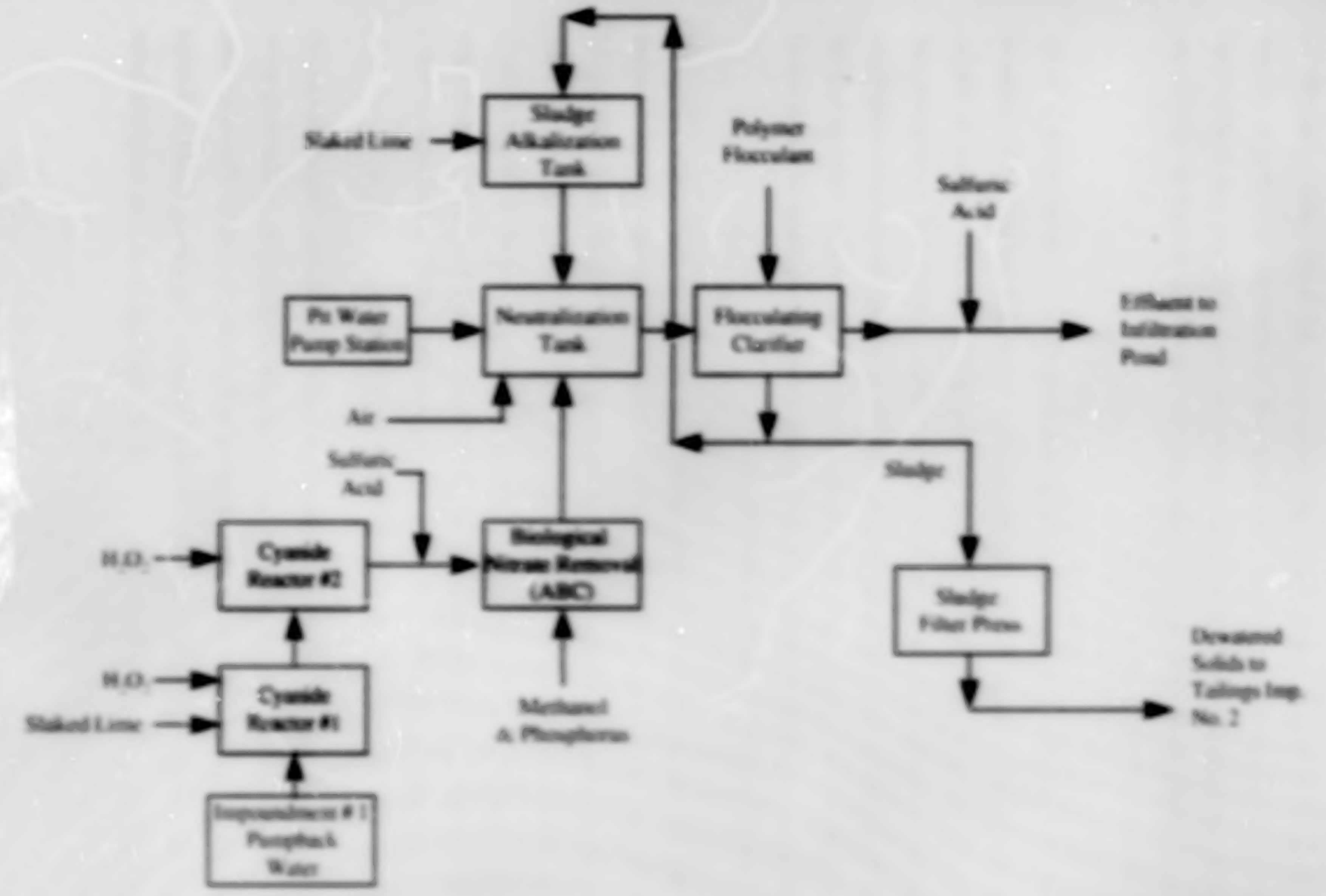

▭ Shaded areas show contingent treatment steps

GOLDEN SUNLIGHT MINE

WATER TREATMENT PLANT WITH CONTINGENCY TREATMENT STEPS

FIGURE **4-2**

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Conventional biotreatment systems have also been used for many years, primarily in municipal wastewater treatment plants. Conventional biotreatment technologies include sequencing batch reactors, rotating biological contractors, and packed-bed and fluidized-bed systems. A simple, effective system for nitrate removal proposed to be used by GSM is the Anoxic Biotreatment Cell (ABC).

The ABC is a porous media-filled, attached-growth denitrification reactor which is under patent-pending status. Denitrification is a biologically enhanced process in which nitrate is converted to nitrogen gas. Several features of the ABC, such as the reactor media, configuration and microbial inoculum, differentiate it from conventional biotreatment and simplify its operation. Based upon site-specific bench-scale test results and prior experience, the ABC is sized to remove a certain concentration of nitrate at the required flow rate and the expected water temperature. Methanol and inorganic phosphate are added to the untreated water to supply required nutrients for microbial growth.

The ABC technology is presently being tested at a number of mine sites. The first production-scale ABC at the Stillwater Mine in Montana significantly exceeded design expectations by removing a high percentage of incoming nitrate (influent concentration = 15 mg/L as nitrogen) at flow rates up to 160 gpm, and has successfully operated at water temperatures far below 10°C. An ABC system is being constructed at the Wharf Mine in South Dakota during the summer of 1997 to remove about 100 mg/L of nitrate at flow rates of 200 to 400 gpm. In addition, two new ABC reactors were added at Stillwater in 1997, which brings the total treatment capacity at this facility to 500 gpm.

If necessary to add treatment for nitrogen removal, the ABC in the Golden Sunlight treatment process could be located after cyanide is removed from Impoundment No. 1 water (Figure 4-2). The ABC would consist of support equipment and the bioreactor itself. The equipment, which would include pumps and mixers for chemical addition, and piping, would be located inside the treatment plant. There would no advantage in locating the bioreactor inside, since it is insulated and located in-ground, so it would probably be outside adjacent to the treatment plant.

It is estimated that the ABC required to treat 200 gpm of Tailings Impoundment No. 1 water would be 20 feet wide, 24 feet long and 8 feet deep. This volume is conservatively based on data from the similar production-scale system at Stillwater, and would be verified during bench-scale testing.

5. COST ANALYSIS OF WATER TREATMENT

Cost estimates were developed for both the proposed action plan and contingency treatment measures based on anticipated long-term flows and water quality. Contingency treatment costs consist of the total treatment plant cost developed for the proposed action plan, plus the costs for contingency treatment. Included in the cost analysis are capital costs, equipment replacement costs, and operating and maintenance (O&M) costs.

5.1 CAPITAL COST ESTIMATES

Treatment costs assume the engineering and construction of all facilities will be performed by independent contractors, not GSM. If GSM performs some or all of these activities, costs could be lower than discussed in this section.

5.1.1 Proposed Action Plan

Following are the assumptions used to prepare capital cost estimates for treatment to meet the proposed action plan:

- The total influent flow to be treated is estimated at 316 gpm.
- The hydraulic capacity of the water treatment plant will be 360 gpm. This provides approximately 15% excess treatment capacity.
- Lime dosages to raise pH of combined stream to the optimum pH of 10.5 were based on experimentally determined dosages for treating pit water quality.

Equipment and pond costs were estimated using the following methods:

- Total cost estimates for the treatment plant were established based on the percentage of delivered-equipment cost (Peters and Timmerhaus 1991). This method for estimating the fixed or total-capital investment requires determination of the delivered-equipment cost. The other items included in the total direct plant cost are then estimated as percentages of the delivered-equipment cost. The additional components of the capital investment are based on average percentages of the total direct plant cost, total direct and indirect plant costs, or total capital investment.

Estimating by percentage of delivered-equipment cost is commonly used for preliminary and study estimates. It yields most accurate results when applied to projects similar in configuration to recently constructed plants (Peters and Timmerhaus, 1991). For comparable plants of different capacity, this method has sometimes been reported to yield the same accuracy as definitive estimates.

The most accurate method of cost analysis is to obtain bids from fabricators, suppliers and contractors (definitive estimates). Since this level of detail was not the focus of this study, generalized cost factors were used instead. The probable accuracy of this study estimate is plus or minus 30 percent.

- Capital equipment estimates were based on budgetary estimates from vendors, produced either for this specific project or from other treatment plants designed by Hydrometrics. The major equipment list and costs are shown in Table 5-1. Total capital costs for the treatment plant are $3.03 million (Table 5-3).

The infiltration pond sized to process the treatment plant effluent of 360 gpm is conservative in two ways: a) it assumes the maximum design flow and b) it does not consider net evaporation at the site. A hydraulic conductivity of 1.5 ft/day was assumed, which is a representative average for the quaternary alluvium present at the proposed pond location (Hydrometrics 1995b). This hydraulic conductivity and flow rate yield a pond size of approximately 46,000 square feet. Utilizing a safety factor of 2 for a ten-foot deep pond yields an excavated volume of approximately 17,100 cubic yards. The total construction cost for the infiltration pond is estimated to be approximately $18,700 (Table 5-2).

The cost for the sludge landfill (Table 5-2) is an engineering estimate. Actual costs for landfill construction cannot be estimated until more information is available to determine the necessary design requirements.

TABLE 5-1. MAJOR EQUIPMENT LIST AND ESTIMATED COSTS FOR PROPOSED ACTION PLAN

EQUIPMENT	DESCRIPTION	CAPITAL COST	REPLACEMENT PERIOD (YR.)
Lime Addition System	90 ton silo, 1 tackle feeder, slaker, feed pump	$175,000	20
Pit Water Pump Station	Two 60 gpm @ 80' TDH pumps, pump house	$30,000	20
Alkalization Tank	800-gal C.S. tank w/coal tar epoxy lining	$6,000	20
Alkalization Tank Mixer	Vertical mount, 2 HP	$3,500	10
Neutralization Tank	15,000-gal C.S. tank w/coal tar epoxy lining	$20,000	20
Neutralization Tank Mixer	Vertical mount, 10 HP	$7,500	10
Clarifier	24-foot diameter with flocculator and scraper	$145,000	30
Polymer Addition System	Automatic polymer prep system	$40,000	20
Polymer Metering Pumps	Progressive cavity pump, 1 gpm, 1 HP	$5,000	10
Sulfuric Acid Tank	6,000 gal carbon steel storage tank	$15,000	20
Sulfuric Acid Metering Pump	Diaphragm metering pump, 7.5 gph, 0.5 HP	$5,000	10
Blower - Neutralization Tank	250 CFM air at 5 psig, 10 HP	$4,000	20
Sludge Recycle Pumps	Two 150 gpm @ 100' TDH, 15 HP centrifugal	$16,000	20
Sludge Holding Tank	20,000-gal C.S. tank w/coal tar epoxy lining	$20,000	20
Sludge Holding Tank Mixer	Vertical mount, 10 HP	$7,500	10
Filter Press and Pump	200-cubic foot press w/ 250 gpm diaphragm feed pump	$190,000	30
Building Sump Tank	500 gal	$3,000	20
Building Sump Pump	25 gpm @ 50' TDH	$2,500	10
TOTAL		$695,000	

TABLE 5-2. ESTIMATED CAPITAL COSTS FOR INFILTRATION POND AND LANDFILL (PROPOSED ACTION PLAN)

ITEM	DESCRIPTION	CAPITAL COST	REPLACEMENT PERIOD (YR.)
Infiltration Pond	46,000 ft² by 10 feet deep	$18,750	N/A*
Sludge Landfill	Est. for access road and initial landfill prep	$25,000	N/A*

*Replacement costs associated with pond and landfill were included as an O&M cost.

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TABLE 5-3. FIXED CAPITAL COST ESTIMATE FOR PROPOSED ACTION PLAN TREATMENT FACILITIES

DESCRIPTION	PERCENTAGE	EST. COST
DIRECT COSTS		
Fabricated Process Equipment	23%	$695,000
Equipment Installation	8%	$242,795
Instrumentation and Controls	6%	$194,236
Piping, Valves and Fittings	7%	$212,445
Electrical and Lighting	5%	$151,747
Buildings and Services	5%	$139,607
Land and Site Work	3%	$84,978
Utilities and Service Facilities	14%	$418,821
Total Direct Costs	71%	$2,142,664
INDIRECT COSTS		
Engineering, Design and Management	9%	$273,144
Construction Expenses and Fees	13%	$388,472
Total Contingencies	7%	$221,350
Total Indirect Costs	29%	$892,271
TOTAL PROJECT COST (FIXED CAPITAL)	100%	$3,034,934

5.1.2 Contingency Treatment

Metals and TDS

As a contingency, treatment costs were developed to treat higher-than-expected water flows (Table 2-1) containing metals and high TDS. Assumptions used in the capital cost estimates for metals and TDS treatment were:

- The hydraulic capacity of the water treatment plant will be 400 gpm. A larger excess treatment capacity was not added because the expected 392 gpm is already a contingency.

Total cost estimates for the treatment plant were established based on percentage of delivered-equipment cost (Peters and Timmerhaus 1991), as discussed in Section 5.1.1. The major equipment list and costs are shown in Table 5-4.

Cyanide Removal

Assumptions used in the capital cost estimates for cyanide treatment were:

- Approximately 200 gpm water from Impoundment No. 1 will require treatment. Cyanide will not be present in Tailings Impoundment No. 2 since tailing will be treated for cyanide before being discharged into the impoundment, and tailing water will be spray-evaporated at closure.

- Tailing water will be treated for cyanide during post-mining years zero to ten. The influent cyanide concentration will be 25 mg/L.

- Cyanide treatment will be performed at pH 10.5 (most conservative), metals removal will be done at pH 10.5 and water discharged to the infiltration pond will be pH 6 to 9.

- Hydrogen peroxide will reduce the total concentration of cyanide in tailing water to 0.2 mg/L.

- After year ten, the tailing water will have a lower pH and require continuous treatment for metals removal. Metals concentrations will be as shown in Table 2-1. The estimated lime dose required for tailing water pH adjustment will be 15 percent of the dose required for pit water. Cyanide concentrations will be low enough in tailings water to eliminate the need for treatment.

TABLE 5-4. MAJOR EQUIPMENT LIST AND ESTIMATED COSTS FOR TDS, METALS, AND CYANIDE TREATMENT

EQUIPMENT	DESCRIPTION	CAPITAL COST	REPLACEMENT PERIOD (YR)
Metals and TDS Removal Equipment			
Lime Addition System	[illegible]	[illegible]	[illegible]
[illegible] Pump Station	[illegible]	[illegible]	[illegible]
Alkalization Tank	[illegible] gal C.S. tank w/coal tar epoxy lining	[illegible]	[illegible]
Alkalization Tank Mixer	Vertical mixer, 2 HP	[illegible]	[illegible]
Neutralization Tank	[illegible] gal C.S. tank w/coal tar epoxy lining	[illegible]	[illegible]
Neutralization Tank Mixer	Vertical mixer, [illegible] HP	[illegible]	[illegible]
Clarifier	[illegible]	[illegible]	[illegible]
Polymer Addition System	[illegible]	[illegible]	[illegible]
Polymer Metering Pumps	[illegible]	[illegible]	[illegible]
Sulfuric Acid Tank	[illegible]	[illegible]	[illegible]
Sulfuric Acid Metering Pumps	[illegible]	[illegible]	[illegible]
Blower - Neutralization Tank	[illegible]	[illegible]	[illegible]
Sludge Recycle Pumps	[illegible]	[illegible]	[illegible]
Sludge Holding Tank	[illegible] gal C.S. tank w/coal tar epoxy lining	[illegible]	[illegible]
Sludge Holding Tank Mixer	Vertical mixer, [illegible] HP	[illegible]	[illegible]
Filter Press and Pump	[illegible]	[illegible]	[illegible]
Backwash Sump Tank	[illegible] gal	[illegible]	[illegible]
Backwash Sump Pump	[illegible]	[illegible]	[illegible]
Subtotal		[illegible]	
Cyanide Removal Equipment			
Hydrogen Peroxide Addition System	[illegible]	[illegible]	[illegible]
Cyanide Reactor No. 1	[illegible] gal C.S. tank w/coal tar epoxy lining	[illegible]	[illegible]
Cyanide Reactor No. 1 Mixer	Vertical mixer, [illegible] HP	[illegible]	[illegible]
Cyanide Reactor No. 2	[illegible] gal C.S. tank w/coal tar epoxy lining	[illegible]	[illegible]
Cyanide Reactor No. 2 Mixer	Vertical mixer, [illegible] HP	[illegible]	[illegible]
Subtotal		[illegible]	
TOTAL		[illegible]	

TABLE 5-5. ESTIMATED CAPITAL COSTS FOR INFILTRATION POND AND LANDFILL (CONTINGENCY TREATMENT)

ITEM	DESCRIPTION	CAPITAL COST	REPLACEMENT PERIOD (YR)
[illegible]			
Infiltration Pond	[illegible]	[illegible]	[illegible]
Sludge Landfill	[illegible]	[illegible]	[illegible]

[illegible]

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Equipment costs for the cyanide removal portion of the contingency treatment system were based on the percentage of delivered-equipment cost, the same method used for the primary treatment system cost estimates. Delivered-equipment cost estimates were based on budgetary estimates from vendors, produced either for this specific project or from other treatment plants designed by Hydrometrics. The major equipment list and costs for cyanide removal are shown in Table 3-4.

The total combined capital cost for a treatment plant to remove metals, TSS and cyanide is estimated to be $[illegible] million (Table 3-6). Capital costs for the infiltration pond and sludge landfill are estimated to be $[illegible] and $[illegible], respectively (Table 3-5).

Nitrate Removal

The assumptions used in contingency treatment for nitrate removal were:

- The total flow requiring treatment will be 200 gpm, which is the anticipated flow from Impoundment No. 1.
- The nitrate concentration must be lowered to below [illegible] mg/L prior to discharge. Assuming some conversion of ammonia in tailing water to nitrate over time, we estimate that a maximum of [illegible] mg/L nitrate (as nitrogen) must be removed in treatment.
- The water temperature for the nitrate removal process would be a minimum of [illegible]°C.
- The concentrations of cyanide and metals would be reduced during cyanide treatment to levels which are non-inhibitory for biological nitrate removal.
- The pH will be controlled between 7 and 8 prior to biological nitrate removal.

Capital costs for nitrate removal, the second part of the contingency treatment system, were calculated differently from those for the other treatment systems. Since costs for this system will include treatability testing, design and process start-up, direct and indirect costs were grouped together (Table 3-7). The total capital cost for nitrate removal is approximately $[illegible].

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TABLE 54. FIXED CAPITAL COST ESTIMATE FOR THE METALS AND CYANIDE TREATMENT FACILITIES

DESCRIPTION	PERCENTAGE	EST. COST
DIRECT COSTS		
Equipment (Process, Fabricated)	[illegible]	[illegible]
Equipment Installation	[illegible]	[illegible]
Instrumentation and Controls	[illegible]	[illegible]
Piping, Valves and Fittings	[illegible]	[illegible]
Electrical and Lighting	[illegible]	[illegible]
Buildings and Services	[illegible]	[illegible]
Land and Site Work	[illegible]	[illegible]
Utilities and Service Facilities	[illegible]	[illegible]
Total Direct Costs	[illegible]	[illegible]
INDIRECT COSTS		
Engineering, Design, Management	[illegible]	[illegible]
Contractors' Expenses and Fees	[illegible]	[illegible]
Total Contingencies	[illegible]	[illegible]
Total Indirect Costs	[illegible]	[illegible]
TOTAL PROJECT COST (FIXED CAPITAL)	[illegible]	[illegible]

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TABLE 5-7 FIXED CAPITAL COST ESTIMATE FOR NITRATE REMOVAL FACILITIES

DESCRIPTION	EST. COST	REPLACEMENT PERIOD (YR.)
DIRECT AND INDIRECT COSTS		
Treatability Testing	$10,000	N/A*
Process Design	$15,000	N/A*
Detailed Design	$40,000	N/A*
Materials and Instrumentation	$120,000	N/A*
Construction and Oversight	$60,000	N/A*
Start-up and Process Support	$25,000	N/A*
Contingencies	$27,000	N/A*
TOTAL PROJECT COST (FIXED CAPITAL)	**$297,000**	

* Treatment is not anticipated to be required for more than ten years.

5.2 OPERATING COST ESTIMATES

Operating costs were estimated using various methods described below. Whenever possible, bench- and/or pilot-scale data were used to estimate reagent quantities.

5.2.1 Proposed Action Plan

Operating and maintenance (O&M) costs for the proposed facilities include chemical reagents, labor, maintenance, electricity and environmental sampling. All operating cost estimates were based on the expected flow of 316 gpm.

Reagent Costs

Reagent costs (Storey 1992) were estimated using 1997 reagent costs from Van Waters and Rogers. Lime dosages for pit water were based on the 1995 average lime addition to the GRM pilot water treatment plant (Storey 1996). Since the pH is raised to only 8.0 in the pilot plant, but the proposed plant would operate at pH 10.5, the treatment plant lime dosage was adjusted upward by a factor of 1.32 based on pit water titration data (Storey 1996). The lime requirement was calculated based on a total water flow rate of 316 gpm. Polymer reagent cost was based on a dosage of 5 mg/L and a dry polymer cost of $1.65/lb.

Sludge Disposal Costs

Sludge volumes were based on 20 percent total solids by weight in the underflow. The settled sludge volume (waste sludge) for treated water was calculated based on GSM data for pit water. Dewatered sludge was assumed to have a total solids concentration of 30 percent by weight. The total dewatered sludge volume to be landfilled was calculated to be 92 yd^3/day.

Costs to dispose the dewatered sludge in the tailings impoundment were estimated using Means Heavy Construction Cost Data (1996) according to the following disposal steps:

- Load dried material into a 12-cubic foot dump truck
- Haul and unload material at the tailings impoundment (1.25 mile round-trip)
- Remove cap on landfill using a dozer
- Consolidate dewatered sludge into a five-foot high pile using a dozer
- Replace capped material on top of sludge material using a dozer
- Re-seed, fertilize, and mulch capped area.

Costs to landfill sludge include contractor's overhead and profit, and assume that all heavy equipment will be rented. Considerable savings could be realized if GSM were to provide the equipment and labor instead of sub-contracting landfill activities.

An alternative method of sludge disposal is to send it as a slurry via pipeline (EIS Appendix C). This cost has not been calculated.

Other Operating Costs

Other operating costs for the plant include labor, supervision, maintenance, power (electricity) and environmental sampling. Labor costs (Storey 1992) were updated to 1997 using an inflation rate of four percent. Supervision and plant maintenance costs were based on two percent of the total capital cost. Annual maintenance costs for the infiltration pond were based on 5% of the capital cost. Electricity costs were calculated using a cost of $0.055/kW-hr and the total plant motor horsepower. Environmental sampling costs were determined based on expected sampling frequencies for parameters of concern.

The breakdown and total for O&M costs are shown in Table 5-8.

TABLE 5-8 ANNUAL O&M COSTS FOR PROPOSED ACTION PLAN TREATMENT FACILITIES

ITEM	EST. ANNUAL COST
Operator	$62,448
Supervision/Admin/R&D	$52,216
Plant Maintenance and Repairs	$51,354
Infiltration Pond Maintenance	$937
Landfill Expansion and Maintenance	$86,750
Lime	$177,120
Sulfuric Acid	$2,370
Polymer Floc	$11,868
Electricity	$27,954
Environmental Sampling	$14,787
TOTAL	$487,805

5.2.2 Contingency Treatment

Operating and maintenance (O&M) costs for contingency facilities include chemical reagents, labor, maintenance, electricity and environmental sampling (Table 5-9). All operating cost estimates were based on the expected flow of 392 gpm.

TABLE 5-9 ANNUAL O&M COSTS FOR CONTINGENCY TREATMENT FACILITIES

ITEM	TDS/Metals Removal	Cyanide Removal*	Nitrate Removal*
Lime	$219,719	-	-
Polymer Floc	$14,159	-	-
Methanol	-	-	$3,000
Phosphate	-	-	$750
Hydrogen Peroxide	-	$57,615	-
Sulfuric Acid	$2,557	-	-
Landfill Expansion and Maintenance	$136,744	-	-
Operator	$62,448	$31,224	$31,224
Supervision/Admin	$60,699	$9,170	$5,940
Plant Maintenance	$60,699	$9,170	$5,940
Electricity	$30,160	$5,670	$6,000
Environmental Sampling	$20,000	$5,000	$5,000
TOTAL	**$607,186**	**$117,849**	**$57,854**

*Years zero through ten only.

Reagent Costs

Lime reagent cost for all low pH water was estimated based on raising the pH of 392 gpm of untreated water from 2.5 to 10.5. For a flow rate of 200 gpm of Tailings Impoundment No. 1 water, it was assumed that a lime dosage of only five percent of the 1995 pit water dosage would be required to raise the pH to 10.5 during years zero to ten. After year ten, when tailing water is predicted to be more acidic, this dosage was assumed to increase to 15 percent of the pit water dosage. Larger dosages are not expected due to the large dilution from groundwater (greater than 10 times).

Methanol reagent cost was based on a dosage of 3 mg methanol per mg nitrogen removed, a nitrate removal of 10 mg/L as nitrogen (to below 7.5 mg/L as N), and a cost of $0.78/gal. The phosphate cost was estimated at 25% of the methanol cost.

Hydrogen peroxide costs were based on a dose of three times that required stoichiometrically for cyanide destruction. Costs and treatment ratios were obtained from Degussa Corporation. Sulfuric acid costs were based on the stoichiometric requirements, plus a considerable safety factor, to reduce the pH of the effluent from 10.5 to 8.5. Chemical reagent costs are shown in Table 5-9.

Sludge Disposal Costs

Sludge volumes produced during treatment of low pH water (not including Impoundment No. 1 water) were based on 20 percent total solids by weight in the underflow. The settled sludge volume (water sludge) for these waters was calculated based on GSM data for pit water. The settled sludge volume for treated tailings water (Impoundment No. 1) was estimated to be 0.25 percent of influent flow for years zero to ten and one percent of influent flow for years after year ten. Dewatered sludge was assumed to have a total solids concentration of 50 percent by weight. The total dewatered sludge volume to be landfilled, from treatment of pit water and tailings water, was calculated to be 61 yd^3/day for years zero to ten and 66 yd^3/day after year ten.

Costs to dispose the dewatered sludge in the tailings impoundment were estimated using the same procedures and assumptions described in Section 5.2.1.

Other Operating Costs

Labor costs were based on an additional half-time operator each for cyanide and nitrate removal. Supervisory and maintenance costs were each estimated at 2% of the respective fixed capital costs for cyanide and nitrate removal (from Tables 5-4, 5-6 and 5-7). Costs for electricity and environmental sampling were estimated based on the requirements for contingency treatment.

6. SUMMARY

6.1 TREATMENT APPROACH

The proposed water treatment plant for Golden Sunlight Mines (GSM) consists of a neutralization tank for metals precipitation, a flocculating clarifier, acidification to meet pH discharge limits, discharge to an infiltration pond, and mechanical dewatering of sludge for on-site landfill disposal in Tailings Impoundment #2. Bench-scale tests showed that lime treatment at pH 10.5 should produce an effluent meeting discharge requirements.

To address future uncertainties associated with water sources, flows and quality, several contingency measures were developed as additional options to the proposed treatment plant. These treatment measures include the need to treat cyanide, nitrate and potentially higher flows for TDS and metals removal. Contingency measures are considered necessary to include at this point, until many of the water management and mitigation measures are implemented at closure. Treatment for cyanide would be accomplished by adding hydrogen peroxide to two reactors operating in series at pH 10.5. Nitrate reduction would be accomplished in a semi-passive biological denitrification reactor prior to discharge. Phosphate and methanol would be added as nutrients for biological growth.

6.2 TREATMENT COSTS

Estimated maximum capital and operating costs for contingency treatment measures are shown in Table 6-1. The fixed-capital investment for a 360-gpm treatment plant to meet action plan requirements, including equipment purchases, installation and all indirect costs, is estimated to be approximately $3.03 million. This was derived from a delivered-equipment cost estimate of $695,000. The total capital cost, including the infiltration pond and landfill, is approximately $3.08 million. Replacement costs are fairly low until year 30. Annual operating expenses are estimated to be approximately $488,000.

Estimated maximum capital and operating costs for contingency treatment measures are shown in Table 6-2. These costs represent the total maximum treatment costs to meet

TABLE 6-1 SUMMARY OF COST ESTIMATES FOR PROPOSED ACTION PLAN TREATMENT FACILITIES

DESCRIPTION	EST. COST
CAPITAL COSTS	
Water Treatment Plant	$3,034,934
Infiltration Pond	$18,741
Landfill	$25,000
Total	$3,078,675
REPLACEMENT COSTS (Including Installation)	
10 Year	$34,444
20 Year	$103,333
30 Year	$634,444
ANNUAL O&M COSTS	
Continuous	$487,895

TABLE 6-2 SUMMARY OF COST ESTIMATES FOR PROPOSED FACILITIES WITH CONTINGENCY TREATMENT

DESCRIPTION	EST. COST
CAPITAL COSTS	
Water Treatment Plant	$3,493,450
Nitrate Treatment Facility	$297,000
Infiltration Pond	$23,630
Landfill	$25,000
Total	$3,839,079
REPLACEMENT COSTS (Including Installation)	
10 Year	$34,444
20 Year	$103,333
30 Year	$634,444
ANNUAL O&M COSTS	
Years Zero to Ten	$782,689
After Year 10	$607,186

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contingency plan requirements. The total capital cost, including TDS, metals, cyanide and nitrate removal as well as the infiltration pond and landfill, is approximately $3.84 million. Cyanide and nitrate removal is assumed to be required for ten years or less. Combined annual operating expenses are estimated at approximately $783,000 during years zero to ten, and $607,000 after year ten.

7. REFERENCES

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ATTACHMENT A-2

GOLDEN SUNLIGHT MINES, INC.
1997 WATER RESOURCES MONITORING PLAN

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Golden Sunlight Mines, Inc.
GSM 1997 WATER RESOURCES MONITORING SCHEDULE

Analytical Code	Parameters Detection limits are shown in parentheses as mg/L. Also includes field parameters pH, specific conductance, and water lever or flow rate.
1	pH Specific Conductivity Total Dissolved Solids (10) Ammonia as N (0.05) NO_3 as N (0.05) Total CN (0.005)
2	Total CN - GSM analyzer (0.005)
3	Ca(1.0), Mg(1.0), P(0.01), F(0.1), Na(1.0), K(1.0), SO_4(5.0), Cl(1.0), HCO_3(1.0), CO_3(1.0) pH Total Alkalinity as $CaCO_3$ (1.0) Total Acidity as $CaCO_3$ (1.0) Ammonia as N (0.05) NO_3 as N (0.05) Specific Conductivity Total Dissolved Solids (10) Dissolved Al(0.1), As(0.005), Ba(0.1), Cd(0.001), Cu(0.01), Fe(0.05), Mn(0.01), Zn(0.01)
4 WQB-7 Reporting Values	Ca(1.0), Mg(1.0), Na(1.0), K(1.0), HCO_3(1.0), CO_3(1.0) P(0.001), F(0.1), SO_4(1.0), Cl(1.0) pH Total Alkalinity as $CaCO_3$ (1.0) Total Acidity as $CaCO_3$ (1.0) Ammonia as N (0.05) NO_3 as N (0.01) Specific Conductivity Total Dissolved Solids (10) Dissolved Ag(0.003), Al(0.1), As(0.003), Ba(0.005), Be(0.001), Cd(0.0001), Cr(0.001), Cu(0.001), Fe(0.01), Hg(0.0006), Mn(0.005), Ni(0.02), Pb(0.003), Sb(0.003), Se(0.001), Tl(0.003), Zn(0.01)

Sampling Method

G Grab
B Bailer
P Pump with Mobile Sampling Unit
I Installed Pump

Additional Parameters

* Plus Total Cyanide

1997 GSM Water Resources Monitoring Schedule

		Winter			Spring			Summer		Fall		
Sample Site	**Method**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
TAILING IMP. AREAS												
GW-10	P	3*			3*			3*		3*		
GW-12	P				1					1		
GW-13	B	3*			3*			3*		3*		
GW-15	B	2			1			2		1		
GW-16	B	2			1			2		1		
GW-17	P	3*			3*			3*		3*		
GW-19	P	2			1			2		1		
GW-21	B	3*			3*			3*		3*		
GWG-1D	B	2			1			2		1		
GW-23	P	2			1			2		1		
GW-24	P	2			1			2		1		
GW-25	P	2			1			2		1		
GW-26	P				1					1		
GW-27	P	3*			3*			3*		3*		
GW-28	P				1					1		
ET-9	B	3*			3*			3*		3*		
ET-11	P				1					1		
GW-33	P	2			1			2		1		
GW-34	P	2			1			2		1		
GW-35	P	3*			3*			3*		4*		
GW-36	P				1					1		
GW-37	P				1					1		
GW-38	P				1					1		
GW-39	P				1					1		
GW-40	P				1					1		
GW-41	P				1					4*		
GW-42	P				1					1		
GW-49	P	3*			3*			3*		3*		
GW-43	P				1					1		
GW-51	P				1					1		
BGW-1	B				1					1		
BGW-4	P				1					1		
BGW-7D	P	2			1			1		1		

* plus TCN

		Winter			Spring			Summer		Fall		
Sample Site	Method	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
TAILING IMP. AREAS - GW-51, GW-52, GW-53, GW-54, GW-60, GW-61, GW-62 T2PB-3, and T2PB-6 also monitored in Dec.												
GW-51	P	2	2	2	1	2	2	2	2	1	2	2
GW-52	P	2	2	2	1	2	2	2	2	1	2	2
GW-53	P	2	2	2	1	2	2	2	2	1	2	2
GW-54	P	2	2	2	1	2	2	2	2	1	2	2
GW-57	P	2			1			2		1		
GW-58	P	3*			3*			3*		3*		
GW-59	P	2			1			2		1		
GW-5 Replacement	P				3*			3*		3*		
New Well West of GW-37	P				3*			3*		3*		
GW-60	P	2	2	2	1	2	2	2	2	1	2	2
GW-61	P	2	2	2	1	2	2	2	2	1	2	2
GW-62	P	2	2	2	1	2	2	2	2	1	2	2
T2PB-3	P	2	2	2	1	2	2	2	2	1	2	2
T2PB-6	P	2	2	2	1	2	2	2	2	1	2	2
OW-2	P	3*			3*			3*		4*		
OW-3	P				1					1		
OW-4	P	3*			3*			3*		4*		
SURFACE WATER - Metals will be analyzed as total recoverable.												
SW-3	G				1					4*		
SW-6	G				1					1		
SW-8	G				1					4*		
RESIDENTIAL - Samples will be collected both before and after R.O. units.												
McCafferty Genzcow	T	1						1				
Jefferson Vet Clinic	T	1						1				
Mt Jct 69 Shop	T	1						1				
N. Tobey	T	1						1				
E. Tobey	T	1						1				
R. Davis	T	1						1				
H. Mulligan	T	1						1				
L. Feight	T							1				
K. Hackathe	T	1						1				
J. Davis	T	1						1				

* plus TCN

		Winter			Spring			Summer		Fall		
Sample Site	Method	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
SOUTH PUMPBACK												
SPB-10	1	2			1			2		1		
SPB-22	1	2			1			2		1		
SPB-28	1	3*			3*			3*		3*		
SPB-30	1	2			1			2		1		
SPB-32	1	2			1			2		1		
SPB-34	1	2			1			2		1		
SPB-37	1	2			1			2		1		
WEST PUMPBACK												
WPB-6	1				1					1		
EAST FLANK PUMPBACK												
EFPB-1	1	3*			3*			3*		3*		
EFPB-4	1	2			1			2		1		
EFPB-8	1	3*			3*			3*		3*		
EFPB-10	1	2			1			2		1		
EFPB-12	1	2			1			2		1		
EFPB-15	1	2			1			2		1		
EFPB-17	1	2			1			2		1		
TAILING PONDS												
Main Dam	G				3*					3*		
Impoundment No. 1	G				1					3*		
Impoundment No. 2	G				1					3*		
Buttress Underdrain E Sump	G				3					3		
Buttress Underdrain W Sump	G				3					3		
PIT & WASTE ROCK AREAS												
PW-3	B	3			3			3		4		
PW-4	P	3			3			3		4		
PW-5	B	3		3		3		3		4		3
PW-6	B	3		3		3		3		4		3
PW-8	P	3		3		3		3		4		3
PW-11	P	3		3		3		3		4		3
PW-12	B	3				3		3		4		
PW-13	B	3			3			3		4		

* plus TCN

		Winter			Spring			Summer		Fall		
Sample Site	**Method**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**
PIT & WASTE ROCK AREAS												
PW-14	P	3		3		3		3		6		3
PW-15	B	3			3			3		6		
PW-16	P	3		3		3		3		6		3
PW-17	P	3			3			3		6		
PW-21	I	3			3			3		6		
PW-22	P	3			3			3		6		
PW-42	P	3			3			3		6		
PW-43	P	3			3			3		6		
PW-44	P	3			3			3		6		
PW-45	B	3			3			3		6		
PW-46	B	3			3			3		6		
PW-47 [illegible]	P	3			3			3		6		
MW-200	P				3					6		
MW-202	P	3			3			3		6		
MW-209	P	3			3			3		6		
MW-210	P	3			3			3		6		
ECW-5	P	3			3			3		6		
EDW-1	I	3			3			3		6		
R-10	B				3					3		
Pit dewatering sump well	G				3					3		
Pit Sumps	G				3					3		
EPHEMERAL DRAINAGES - Sample collected if flow is present												
[illegible] 1	G				3					6		
[illegible] 2	G				3					6		
[illegible] 3	G				3					6		
Sheep Rock 1	G				3					6		
SPRINGS												
[illegible] North	G				3					6		
Sheep Rock Draw	G				3					6		
[illegible] Original	G				3					6		
[illegible]	G				3					6		
Widow Drain	G				3					3		
Rattlesnake Wells	I				3					6		

* plus TCN

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APPENDIX B

WATER QUALITY REGULATORY COMPLIANCE AND APPLICATION FOR SOURCE-SPECIFIC GROUNDWATER MIXING ZONE

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APPENDIX B

WATER QUALITY REGULATORY COMPLIANCE AND APPLICATION FOR SOURCE SPECIFIC GROUNDWATER MIXING ZONE

GOLDEN SUNLIGHT MINES, INC.

Submitted by:

Golden Sunlight Mines, Inc.
453 MT Highway 2 East
Whitehall, MT 59759

Prepared by:

Hydrometrics, Inc.
2727 Airport Road
Helena, M[illegible]9601

August 1997

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APPENDIX B

WATER QUALITY REGULATORY COMPLIANCE AND APPLICATION FOR SOURCE SPECIFIC GROUNDWATER MIXING ZONE

GOLDEN SUNLIGHT MINES, INC.

1.0 INTRODUCTION

Golden Sunlight Mines, Inc. (GSM) operates an open pit gold mine located in the southern end of the Bull Mountains near Whitehall, Montana. GSM was granted a Hard Rock Operating Permit (00065) on June 27, 1975. However, mine construction did not occur at that time as heap leaching of sulfide ore was tested and proved unsuccessful. In 1980, GSM proposed significant expansion of mining activity and a cyanide vat leaching process (Amendment No. 1 to Permit 00065). After completion of an EIS, Amendment 001 was approved in 1981. Mine construction at GSM began in 1982 with construction of Impoundment No. 1. Additional expansions of the mine were permitted by several minor permit amendments between 1983 and June 1990. Amendment 008 to GSM's Operating Permit was granted after completion of a mitigated Environmental Assessment (EA) on July 1, 1990. Amendment 008 allows expansion of the open pit, expansion of the East and West Waste Dumps, construction of Impoundment No. 2, and minor modifications to mine support facilities. As the result of a Montana District Court ruling an Environmental Impact Statement for Amendment 008 (Part of EIS Proposed Action) is currently being developed by the Montana Department of Environmental Quality (MDEQ) and the Bureau of Land Management (BLM).

1.1 REGULATORY REQUIREMENTS AND PURPOSE

It is recognized (see EIS) that mine facilities such as waste dumps, tailings impoundment's, and treated pit dewatering discharges, have resulted or could result in discharges to groundwater. In accordance with Montana groundwater regulations (ARM

16.20.1012(1)(m)), these groundwater discharges are exempt from discharge permit requirements of the Montana Groundwater Pollution Control System (MGWPCS). Although these discharges are exempt from MGWPCS permits, Montana Groundwater Quality Standards (ARM 16.20. 1003), Nondegradation of Water Quality rules (ARM 16.20.700), and restrictions and prohibitions of Mixing Zones in Groundwater rules (ARM 16.20. 1800) are still applicable to the discharges. Discharges to groundwater are allowed through GSM's Hard Rock Operating Permit and Amendments. Although groundwater mixing zones previously have not been explicitly identified for the GSM permit area, mixing zones have been used at GSM most notably associated with seepage from Impoundment No. 1 that occurred in 1983. The actions of the former DHES acknowledged and approved GSM's expeditious and effective handling of this seepage and constituted a clear recognition of a de facto mixing zone from Impoundment No. 1 to the GSM property boundary.

The purpose of this Mixing Zone Application is to delineate and request formal approval by MDEQ of a mixing zone for groundwater within the GSM permit area. This mixing zone covers previously permitted facilities and existing discharges as well as proposed facility expansions and potential future discharges. This Mixing Zone Application both requests a mixing zone for the GSM facility and provides the information demonstrating that the proposed mixing zone complies with restrictions and prohibitions of the Groundwater Mixing Zone rules and will be protective of beneficial uses of groundwater. Should the proposed action result in groundwater concentrations above the proposed compliance limits contingency actions are also described.

1.2 DESCRIPTION OF SOURCES OF GROUNDWATER DISCHARGES

Sources of groundwater discharge at the GSM Facility include existing sources (Impoundment No. 1); existing sources that may discharge in the future (East and West Waste Dumps and pit water) and proposed sources that will be constructed and will discharge in the future (treatment plant discharge to infiltration basin). The water handling and water management plan for groundwater discharges are described in detail

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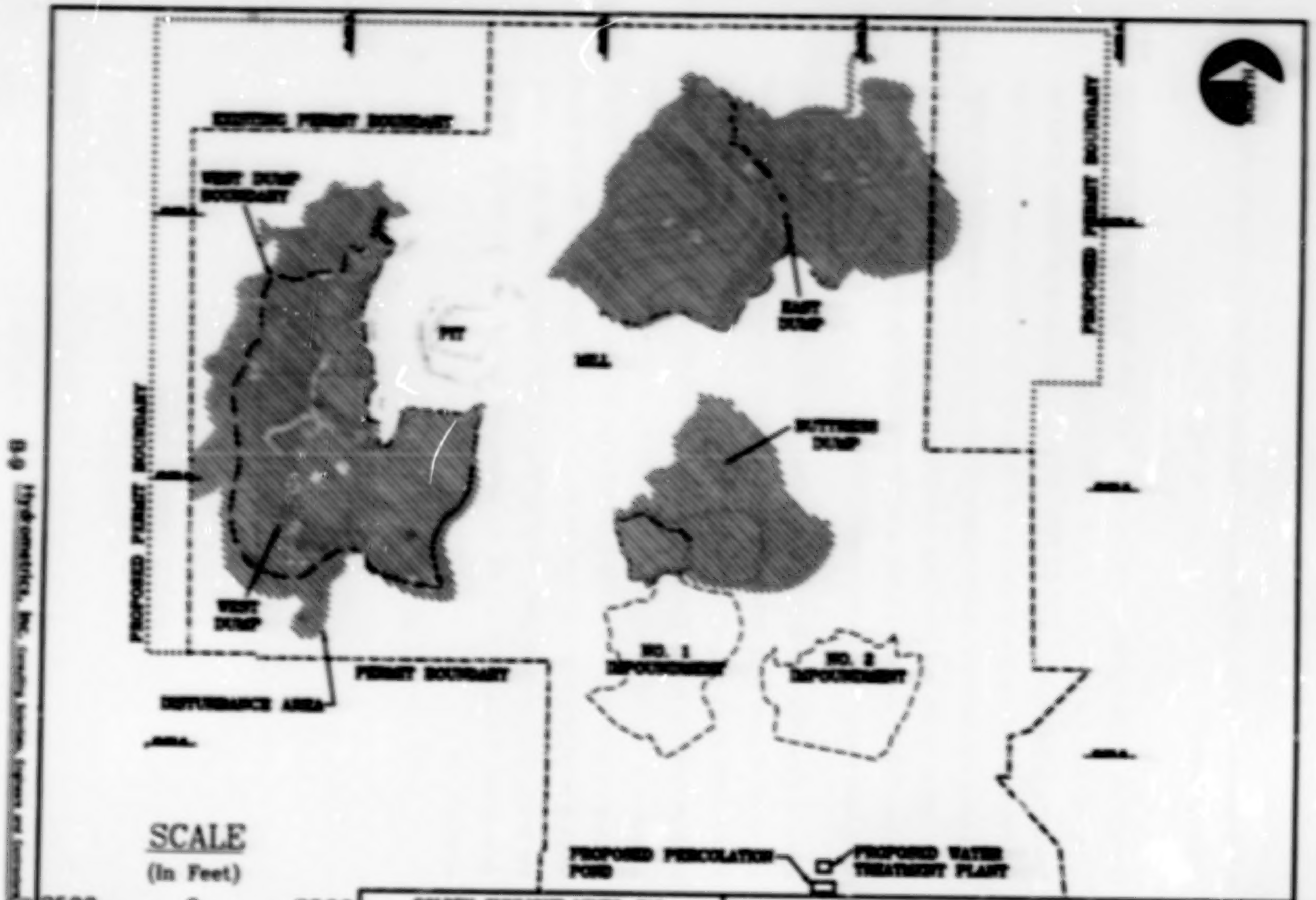
in EIS Appendix A (Hydrometrics, 1997a). Facilities layout under the Proposed Action is shown in Figure 1-1.

Groundwater discharge from Impoundment No. 1 began in 1983 through a deficiency in a slurry wall that was constructed as part of the tailings water containment system (see discussion in Section III.B.2.f of the EIS). This failure resulted in the release of tailings water to the underlying groundwater system. Soon after the release was discovered, GSM constructed a groundwater capture (pumpback) system to limit migration of the seepage. This capture system has effectively controlled tailings seepage and continues to be operated. GSM's proposed dewatering and reclamation of the impoundment is expected to minimize seepage from the impoundment area.

Based on groundwater monitoring data, studies of waste dump moisture characteristics, and models of waste dump water transport mechanisms; the East and West Waste Dumps are not currently discharging to groundwater. However, it is predicted that infiltration moisture from the dumps could discharge to groundwater at some time in the future. Estimates of the time at which seepage could occur vary from several tens to several hundreds of years (Appendix J, EIS). The seepage from the West Dump will be captured either in drains or groundwater capture wells for treatment and discharge by the proposed permanent water treatment plant. Seepage from the East Dump will enter the underlying groundwater system where acidity and metals will be attenuated by natural geologic materials.



GOLDEN SUNLIGHT MINES, INC.
APPLICATION FOR SOURCE SPECIFIC
GROUNDWATER MIXING ZONE

FACILITIES LAYOUT UNDER
PROPOSED ACTION

FIGURE
1-1

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B-9 Hydrometrics, Inc. [illegible]

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Impoundment No. 2 was constructed with an HDPE liner over compacted clay material to prevent discharge to groundwater. Cyanide has been detected at concentrations just above the laboratory detection limit (0.005 mg/l) in monitoring wells adjacent to the east reclaim water basin. GSM corrected defects in the east reclaim basin liner system in 1995 and 1996 to eliminate the leakage (see discussion in Section III.B.2.f of the EIS). Following closure and reclamation of the impoundment, the only flow from the impoundment underdrain will be from infiltration of precipitation through the reclamation cover. This underdrain discharge will report to the permanent treatment plant and will be discharged to an infiltration basin following treatment.

GSM currently operates a small scale water treatment plant to treat water from pit dewatering. This treated pit water currently is used in GSM's milling circuit and is not discharged to the environment. Following mine closure the milling circuit will no longer operate. After the approximately 30 years required for the pit to fill to the 5,050 feet elevation, pit water will be directed to the permanent water treatment plant and ultimately discharged to an infiltration basin following treatment. During the 30 years of pit filling, the pit will act as a hydrologic sink and no pit water will be discharged.

The permanent water treatment plant will handle flows from Impoundment No. 2 underdrain, Impoundment No. 1 pumpback water, pit inflow water, and any water from the West Waste Dump capture system. Treated water will be discharged to groundwater through an infiltration basin proposed to be located below (south) of Impoundment No. 2. A contingency water treatment plant design has also been developed (see EIS Appendix A, Hydrometrics, 1997b) that would accommodate additional flows from other sources if additional groundwater capture systems are needed.

2.0 QUANTITY, TOXICITY, AND PERSISTENCE OF DISCHARGES

This section describes the rates and chemical concentrations (quantity) of existing and proposed discharges and the length of time that discharges are estimated to occur (persistence). Toxicity of discharges is described by comparison of chemical concentrations in discharges with Montana Human Health Standards.

2.1 ACID ROCK DRAINAGE FROM WASTE ROCK

Ore and waste rock materials in the Golden Sunlight deposit (Bull Mountain) contain sulfide minerals, primarily pyrite, that when oxidized and exposed to water produce acidic metal-bearing solutions referred to as acid rock drainage (ARD). Production of natural ARD from Bull Mountain occurred for a very long time prior to mining (estimated approximately 27,000 years; Appendix J of the EIS). During and after removal of waste rock in GSM's mining process, these materials are expected to continue to generate ARD for a very long time. Although the waste rock dumps are not currently releasing ARD to groundwater, based on field evidence and predictive modeling, it is predicted that within several tens of years to several hundreds of years (Appendix J, EIS) seepage of ARD from the dumps could reach the underlying groundwater. This section discusses the estimated quantity and quality of seepage from the waste rock dumps and the length of time that seepage of ARD is expected to occur.

2.1.1 Quantity of Waste Rock Seepage

Based on field evidence and predictive modeling, waste dump seepage's are estimated to range from 7 to 14 gpm for the West Dump and 10.5 to 21 gpm from the East Dump (Appendix J, EIS) following reclamation. Unreclaimed portions of the dumps may yield seepage rates on the order of four times higher than the reclaimed dumps.

2.1.2 Quality of Waste Rock Seepage

Because seepage from waste rock is not occurring presently, actual seepage cannot be measured. However, GSM has sampled porewater within the waste rock (see, GSM, 1995). This porewater will migrate downward through the dumps and underlying vadose zone and will ultimately mix with the underlying groundwater. Analyses of porewater from reclaimed dumps, therefore, provide the best available estimate of long-term waste rock seepage quality. Detailed data for sulfate concentration of porewater samples is given in GSM (1995). Based on this data, sulfate concentration in reclaimed dumps varies from 26,300 to 37,500 mg/l. From this data, the EIS (Appendix J) assumes an average sulfate concentration of 30,000 mg/l in porewater from reclaimed dumps. For purposes of this mixing zone analysis a sulfate concentration of 30,000 mg/l is also assumed. Additional data on metal concentrations in porewater is summarized in Table 2-1.

2.1.3 Acid Rock Drainage Persistence

As discussed in Section 2.1.1, waste rock dumps are not currently releasing ARD to groundwater based on field evidence and predictive modeling. Seepage is not expected to occur from the Waste Rock Dumps for 50 to 350 years due to the low recharge rates associated with the final dump reclamation design (0.25 inches/yr.) and the huge volume of material through which the seepage must pass. Once seepage emerges from the bottom of the waste rock dumps it must pass through an additional 300 feet of unsaturated Bozeman Group sediments before reaching the regional water table. Travel times in excess of 800 years have been predicted for seepage from the east dumps to reach groundwater (EIS Appendix J). ARD concentrations in seepage will be affected by attenuation and neutralization within the Bozeman, dilution in the regional groundwater system and additional dilution by precipitation recharge and dispersion as groundwater flows downgradient.

Table 2-1. SUMMARY OF WASTE ROCK POREWATER SULFATE AND METALS CONCENTRATIONS WATER QUALITY REGULATORY COMPLIANCE AND APPLICATION FOR SOURCE SPECIFIC GROUNDWATER MIXING ZONE

		Concentration (mg/l)										
Site	**Depth (ft)**	**SO_4**	**As**	**Cd**	**Cu**	**Cr**	**Fe**	**Pb**	**Mn**	**Ni**	**Se**	**Zn**
SM2	5	1390	0.004	0.0024	4.59	1.06	4.59	<0.003	0.931	0.2	0.002	0.33
SM3	10	2020	<0.003	0.066	5.97	0.053	2.15	<0.003	31.5	1.69	<0.001	3.55
SM6	10	13600	1.47	0.136	18.3	1.27	2470	<0.003	11.1	3.63	0.046	7.6
SM1	10	14300	0.017	<0.0001	1.51	0.048	267	<0.003	2.07	0.39	0.001	0.58
SM2	40	80500	0.033	0.242	86	0.168	66.2	<0.003	19	3.03	<0.001	27.7
Mean		7827.5	0.498	0.0681	7.59	0.608	685.94	<0.003	11.400	1.48	0.016	3.02
Geometric Mean		8484.1	0.047	0.0478	9.18	0.225	53.32	<0.003	6.629	1.08	0.005	2.70

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The length of time that waste rock dumps will contribute ARD seepage is dependent on the amount of sulfide material or pyrite in the dumps and the rate of infiltration of precipitation into, and seepage out of, the dumps. Based on the minimum and maximum predicted infiltration rates, ARD seepage from the East Waste Dump is predicted to occur for approximately 2,000 to 7,000 years (see Figures J-8 and J-9 of the EIS). Based on the minimum and maximum predicted infiltration rates, ARD seepage from the West Waste Dump is predicted to occur for approximately 2,000 to 12,000 years (see Figures J-22 and J-23 of the EIS).

2.2 TREATMENT PLANT DISCHARGE

GSM currently operates a small-scale treatment plant to treat ARD water from pit dewatering. Treated water is used in the mill process circuit. Under GSM's reclamation plan, a permanent water treatment plant would be built to treat pit water, potential toe drain discharge from the West Waste Dump, potential groundwater captured from the West Waste Dump groundwater interception system, Impoundment No. 2 underdrain discharge, and Impoundment No. 1 pumpback well water.

GSM's small-scale treatment plant treats acidic pit waters by lime neutralization to precipitate metals followed by simple settling in inclined plate clarifiers. In this process, acidic waters are neutralized with lime to remove the majority of metals from solution. This process produces a sludge of precipitated metals and effluent water that has near neutral to alkaline pH (typically around pH 8) and low metal concentrations. The permanent treatment plant would use a similar lime neutralization technology for metals removal, but is designed to improve sludge densities thereby reducing sludge volumes.

2.2.1 Treatment Plant Discharge Rates

Treatment rates and discharge rates are estimated to be approximately 316 gpm under the Proposed Action (54 gpm from pit, 52 gpm from West Dump capture wells, 200 gpm from Impoundment No. 1, and 10 gpm seepage from Impoundment No. 2 underdrain; see EIS Appendix A).

2.2.2 Treated Water Quality

Estimates of treated water quality are presented in Appendix A of the EIS and are summarized in Table 2-2. These estimates are based on data from GSM's operating pilot plant and results of laboratory scale treatment tests (jar tests). As the results in Table 2-2 demonstrate, the concentrations of metals and sulfate in treated water are dependent on the pH at which the treatment plant is operated. In general, at higher pH values, lower effluent metal concentrations are achieved. GSM will likely operate the treatment plant at a pH of 10.5 because treatment to such a level yields water similar in quality to ambient groundwater in the area. The pH of treated water will be adjusted downward to the range of 6 to 9 through the addition of sulfuric acid.

Presently, the primary sources of nitrate in feed water to the proposed treatment plant are pit water, tailings water, and dump porewater. The source of nitrate in pit water is from blasting agents used in the mining process. After cessation of mining and blasting, the source of nitrate will no longer exist and nitrate concentrations in pit water will decrease quickly to background concentrations of less than 1 mg/l. Nitrate concentrations in dump porewater will likely remain low (approximately 2 mg/l) but elevated above background for a very long time due to the very slow rate at which water moves through the dumps. The sources of nitrate in tailings water are residual blasting agents and degradation of cyanide. Nitrate concentrations in tailings water may initially increase for a period of time due to cyanide degradation and conversion of ammonia to nitrate, before decreasing to background concentrations as cyanide and nitrogen are flushed from the tailings.

Following mine closure, the predominant source of nitrate to the treatment plant (pit water and Impoundment No. 1 pumpback water) will rapidly diminish and approach background groundwater concentrations of 1 mg/l. A long-term estimate of nitrate concentrations from the treatment plant is approximately 5.7 mg/l (Appendix A of the EIS).

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Table 2-2. Estimated Water Treatment Plan Effluent Quality

									Concentrations (mg/l)									
	pH (s.u.)	TDS	SO_4	NO3 + NO2-N	Al	As	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn
Neut. Pit Water (1)	7.5	10000	6400	*	<0.1	<0.005	0.018	NA	0.03	<0.03	<0.01	7.79	NA	NA	NA	NA	0.34
Neut. Pit Water (2)	8	6750	5667	*	0.379	<0.001	0.005	0.021	0.019	<0.05	0.003	0.584	NA	0.012	NA	NA	<0.05
Neut. Pit Water (2)	9	5310	3542	*	0.144	0.002	0.001	0.024	0.026	<0.05	0.004	<0.05	NA	<0.001	NA	NA	<0.05
Neut. Pit Water (2)	10	4120	3270	*	<0.05	0.001	<0.001	0.021	0.008	<0.05	0.001	<0.05	NA	<0.001	NA	NA	<0.05
Neut. Pit Water (2)	10.5	2710	2700	*	<0.05	0.001	<0.001	0.016	0.007	<0.05	<0.001	<0.05	NA	<0.001	NA	NA	<0.05
Thickener Overflow (3)	NA	NA	5000	*	<0.05	0.003	0.006	0.003	0.076	<0.05	0.003	0.184	NA	<0.001	NA	NA	0.061
Thickener Overflow (4)	8.62	8621	5446	*	0.127	0.004	<0.001	0.003	0.035	<0.05	0.003	0.318	NA	<0.005	NA	NA	<0.05

Notes:

NA = not analyzed

*** Predicted nitrate + nitrite concentration in treated effluent is 5.74 mg/l (see Appendix A of EIS).**

(1) Source: August 1993 Stage II Pit treated water quality from September 29, 1993 Golden Sunlight memo from N. Gallagher to F. Foster.

(2) Source: Results of September 1993 laboratory test.

(3) Thickener overflow from pilot plant sampled May 26, 1994.

(4) Thickener overflow from pilot plant sampled July 16, 1994.

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2.2.3 Persistence of Treated Water

The permanent treatment is proposed to be operated in perpetuity to treat pit waters, water capture by the West Dump seepage capture system, and drainage from Tailing Impoundments No. 1 and No. 2.

2.3 IMPOUNDMENT NO. 1 SEEPAGE

Seepage from Impoundment No. 1 to groundwater began in 1983 through a deficiency in the slurry cut-off wall below the impoundment. This seepage of cyanide-bearing water was detected during routine groundwater monitoring by GSM in April 1983. GSM immediately began remedial actions to repair the slurry wall and to construct pumpback wells (SPB wells) to capture and control seepage migration. Additional pumpback wells were installed in 1984 (EPB wells) and during 1990 - 1991 (second and third row of SPB wells, and EFPB wells). Presently, the areal extent of the cyanide-bearing groundwater plume resulting from the seepage is generally limited to within 600 to 800 feet of the impoundment along its eastern and southeastern flanks (see Section III.B.2.f of the EIS).

Ongoing work to dewater and reclaim the impoundment is expected to greatly diminish, but not eliminate, seepage and discharge to groundwater from the impoundment. Long-term discharge from the impoundment will be at lower rates than have occurred previously, due to a reduction in infiltration through the reclamation cap (expected to be approximately 0.25 inches/yr.).

2.3.1 Seepage Water Quantity

The present rate of seepage from the impoundment is not known with certainty, but can be estimated based on the past and present sources of water to the impoundment. Present sources of seepage water include rainfall infiltration (1.5 inches/yr. or approximately 15 gpm) into the unreclaimed impoundment surface combined with water released from storage as tailings are dewatered. This then mixes with an estimated 100 to 200 gpm of groundwater within the underlying Rattlesnake hydrostratigraphic unit. Until mid-1996,

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water from the pumpback wells also was occasionally discharged back into the tailings impoundment at the rate of several hundred gallons per minute. The present and historic rates of seepage from the impoundment combined with groundwater underflow in the Rattlesnake area is approximately 260 gpm (the present rate of flow from pumpback systems). This rate is expected to decrease to less than 200 gpm as the tailing is dewatered.

Under the proposed action, GSM will reclaim the impoundment to minimize rainfall infiltration. After reclamation, rainfall infiltration is estimated to be 0.25 inches/yr. (see Section IV.B.2.c of the EIS) or approximately 2 gpm. After dewatering of the impoundment is completed within approximately 7-10 years, seepage rates will approximately equal the rainfall infiltration rate of 2 gpm. Long-term seepage rate from the impoundment is estimated to be 100 times lower than the current pumpback well capture rate. GSM has conservatively estimated a long-term flow of 200 gpm of pumpback well water from Impoundment No. 1 (most of which would be Rattlesnake unit groundwater) into its long-term treatment plant design.

2.3.2 Seepage Water Quality

The quality of historic seepage from the impoundment has been variable. During active use of the impoundment, seepage water contained several hundred mg/l of cyanide and cyanide-metal complexes and was alkaline due to the presence of mill processing reagents. The impoundment no longer receives cyanide-bearing discharges from the milling circuit and, as the result of natural cyanide degradation processes, currently contains much lower concentrations of cyanide. Current water quality of tailings water is presented in Table 2-3.

TABLE 2-3. ESTIMATED IMPOUNDMENT NO. 1 SEEPAGE WATER QUALITY

	pH (s.u.)	Concentrations (mg/l) TDS	SO_4	NO3 + NO2-N	Al	As	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn
Current Seepage Quality (1)																	
Mean	7	5851	3622	4	0.128	0.017	0.002	ND	15.1	48.8	0.01	4.7	0.008	2.36	0.035	0.005	0.054
Minimum	6.6	2480	3050	0.96	0.1	0.005	0.0008	ND	7.22	1.4	0.01	0.59	0.001	1.58	0.005	0.005	0.01
Maximum	9.0	7060	4020	8.9	0.25	0.056	0.004	ND	28.9	104	0.01	8.5	0.015	3.32	0.093	0.005	0.18
Long-Term Seepage Quality (2)																	
Mean	2.7	15698	10240	10.9	292	0.411	0.641	0.009	75.9	1170	0.274	126	NA	5.61	0.015	NA	90.4
Minimum	2.4	7540	4900	1.31	28	0.012	0.017	0.009	2.56	14.1	0.0075	28.5	<0.0002	1.65	0.0063	<0.004	19.3
Maximum	3.5	28100	18100	24.3	1420	1.49	3.93	0.009	343	3490	1.09	652	<0.001	11.2	0.023	<0.005	248

Notes:

NA = not applicable

ND = no data

(1) Current seepage quality estimated from Impoundment No. 1 Main Drain samples (see Attachment 1); below detect data replaced with the detection limit for calculations.

(2) Long-Term seepage quality estimated as equivalent to mine pit water quality (see Appendix A of EIS).

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Tailings contain sulfide minerals which after dewatering will likely oxidize and produce ARD similar to the waste dumps and pit. Over time, seepage quality could approach the quality of pit water. For comparison, pit water quality is also presented in Table 2-3.

2.3.3 Seepage Persistence

Because seepage from the impoundment is driven by rainfall infiltration, some low rate of seepage from the impoundment likely will occur in perpetuity.

3.0 WATER-BEARING CHARACTERISTICS OF SUBSURFACE MATERIALS

A detailed description of the groundwater system in the GSM project area is given in Section III.B.2 of the EIS and GSM (1995). The following sections summarize information presented in these documents. Additional information about the groundwater systems near groundwater discharge sources is included in Section 4.0.

3.1 HYDROSTRATIGRAPHY

Groundwater at the GSM mine area occurs in five principal hydrostratigraphic units:

Precambrian fractured bedrock - This unit is the primary hydrostratigraphic unit in the areas of Bull Mountain and the western portion of the permit area. This unit includes siltstone, mudstone, sandstone, and shale lithologies. Bulk permeability estimates for the unit generally range from 10^{-6} to 10^{-7} cm/sec.

Tertiary Bozeman Group - This unit occurs east and south of Bull Mountain overlying bedrock. The Bozeman Group is composed of layers of sand, silt, and clay deposited in a fluvial environment. Bulk permeability estimates for the unit generally range from 2.5×10^{-3} to 7×10^{-6} cm/sec.

Tertiary/Quaternary colluvium and alluvium - This unit consists of gravels in a silty sand matrix overlying the Bozeman Unit on the east flank of Bull Mountain and in modern drainages.

Debris flow/colluvial materials - This unit is present in localized areas on the east side of Bull Mountain, principally in the Rattlesnake Gulch area.

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Jefferson River alluvium - This unit is composed of alluvium associated with the Jefferson River hydrologic system in the southern portion of the project area.

3.2 RATE AND DIRECTION OF GROUNDWATER FLOW

A regional potentiometric map of the mine area is presented in Section III.B.2 of the EIS. Water levels from shallow/deep well pairs indicate a general downward component of flow within the mine area. Groundwater generally flows to the southeast, south, and southwest in a radial pattern from bedrock in Bull Mountain to the Bozeman Group unit in lower elevations. Groundwater flow in the Bozeman Group discharges to the Jefferson River alluvial aquifer along the southern boundary of the project area.

3.3 AMBIENT GROUNDWATER QUALITY

Groundwater quality in the mine area is highly variable between hydrogeologic units and also depending on location relative to Bull Mountain and the sulfide ore zone. Because of this variability, various groundwater regions have been delineated for evaluation purposes. These groundwater regions are shown on Figure 3-1. Attachment 1 includes tables of summary water quality statistics for the groundwater regions and water quality data from which these summary statistics are derived.

3.4 EXISTING BENEFICIAL USES

Beneficial uses in the GSM vicinity are identified in Section IV.B.1 of the EIS. Within the proposed permit boundary there are no agricultural or domestic water supply uses. Beneficial uses within the proposed permit area are limited to wildlife use of several springs (Steppan Original Spring, Bunk House Spring, and Rattlesnake Spring). Outside of the permit area, domestic uses occur in locations near I-90: southwest of the West Dump Complex and southeast of Impoundment No. 2. All domestic uses utilize groundwater within the Jefferson River alluvium which receives some recharge from the Bozeman Group and the bedrock unit. Ambient water quality for these domestic uses is summarized in Attachment 1.

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4.0 GROUNDWATER MIGRATION AND PREDICTED GROUNDWATER CONCENTRATIONS

This section discusses factors affecting chemical concentrations in the groundwater systems. These factors include mixing/dilution with ambient groundwater and precipitation recharge, neutralization or chemical attenuation of ARD by vadose zone and aquifer materials, and capture of affected groundwater and waste-rock seepage. Each of the four facilities (East Waste Dump, West Waste Dump, Impoundment No. 1, and treatment plant discharge) are evaluated individually in this section because each facility has unique discharge quantities and qualities as well as a unique hydrogeologic setting.

4.1 EAST WASTE ROCK DUMP

The boundary of the existing and proposed expansion of the East Dump is located entirely on sedimentary material of the Bozeman Group. These sedimentary materials are typically calcareous and contain approximately 5 percent calcite. Seepage from the East Dump would travel through the underlying unsaturated materials and eventually (within an estimated 1,000 years, EIS Appendix J) could mix with groundwater in the Bozeman Group. Processes that will affect chemical concentrations are chemical reaction and neutralization of acidity by vadose zone and aquifer materials, dilution by upgradient groundwater, and additional dilution by precipitation recharge to the groundwater system.

A simple mixing and mass balance model to predict sulfate concentrations versus time at discrete distances from the East Dump is presented in the EIS (Appendix J). The mixing cell model predicts that full chemical neutralization of ARD seepage from the East Dump could occur between 2,200 and 4,400 feet from the toe of the dump, depending on the assumed seepage rate. Furthermore, the mixing cell model predicts that sulfate concentrations ranging from 800 to 1,300 mg/l could occur in groundwater before it mixes with the Jefferson River alluvial aquifer in 2,000 to 12,000 years (see Figures J-8 and J-9, Appendix J, EIS). The EIS also predicts that metal concentrations in groundwater at the toe of the dump could range

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from the concentrations currently present (background concentrations) to concentrations similar to dump porewater (see Table J-5, Appendix J, EIS). Refinement of the EIS estimate of metal concentrations in groundwater downgradient of the dump at the point of full neutralization of ARD is needed to delineate the proposed mixing zone boundary.

Based on the mixing cell model in Appendix J of the EIS, full neutralization of ARD is expected to occur within 4,400 feet from the dump under worst-case conditions. Metal concentrations at the point of full neutralization can be estimated based on column attenuation tests of Bozeman Group materials. Column attenuation test methods and results are described in Schafer ((1994). In this study, two columns (3 inches by 30 inches) containing Upper and Lower Bozeman Group materials were leached with simulated ARD water. Simulated ARD water (pH 1.88) consisted of de-ionized water matrix with the following ionic concentrations:

Metal	Concentration (mg/l)
aluminum	3,000
iron	2,000
copper	380
arsenic	10
manganese	134
zinc	130
cadmium	0.6
molybdenum	0.3
selenium	1.0
sulfate	23,000
chloride	100

Based on sulfate concentration, the simulated ARD water used in the column tests approximates dump porewater. However, the metal concentrations in simulated ARD (e.g. iron 2,000 mg/l) generally were much higher than have been observed in dump porewater (e.g. mean iron 685 mg/l). In the column tests, Bozeman Group materials were found to fully neutralize the first one to two pore volumes of ARD water. A comparison of column effluent water chemistry with Montana Human Health Standards and ambient groundwater chemistry is presented in Table 4-1. As these results demonstrate, Bozeman Group materials effectively neutralize ARD to a pH of approximately 7, and concurrently greatly reduce metal concentrations. Metal concentrations in neutralized ARD water are, with few exceptions, similar to Montana Human Health Standards and ambient groundwater quality.

It should be noted that the column tests most closely approximate attenuation of ARD in the unsaturated or vadose zone. In the groundwater system, metal concentrations would be further reduced by dilution with ambient groundwater and by neutralization by the alkalinity of ambient groundwater. Although nominal differences occur between column effluent concentrations, water quality standards, and ambient groundwater, for purposes of mixing zone or compliance point determination available data conservatively suggests that seepage from the East Dump should be similar to ambient groundwater quality and Human Health Standards within approximately 4,400 feet from the toe of the dump.

4.2 WEST WASTE ROCK DUMP

Groundwater quality downgradient of the east and west flanks of the West Waste Dump after mine reclamation has been estimated using a groundwater mixing model. The inputs to the model and model assumptions are detailed in this section.

The groundwater mixing model assumes that downgradient concentrations will be determined by simple mixing and dilution. Constituent loads from various sources are combined in the model to yield an overall downgradient load; no geochemical interactions (such as adsorption or precipitation/dissolution of solids) have been considered. Thus, concentrations can be determined from the following equation:

TABLE 4-1. COMPARISON OF EAST SIDE SOIL ARD NEUTRALIZATION/ATTENUATION TEST RESULTS WITH AMBIENT GROUNDWATER QUALITY

			Concentrations (mg/l)										
Water Type	**pH (s.u.)**	**SO_4**	**As**	**Cd**	**Cu**	**Cr**	**Fe**	**Pb**	**Mn**	**Hg**	**Ni**	**Se**	**Zn**
Simulated ARD	1.88	23000	10	0.6	380	ND	2000	ND	134	ND	ND	1.0	130
Neutralization/Attenuation Column Test Effluent[1]													
Upper Bozeman	6.84	3994	0.19	<0.02	<0.2	<0.2	<0.6	<0.2	<0.2	<0.001	<0.2	<0.005	<0.2
Lower Bozeman	7.74	3309	0.016	<0.01	1.0	<0.1	0.38	0.015	<0.1	<0.001	0.12	<0.005	0.13
Ambient Groundwater Quality													
Region 1B[2]													
Geometric Mean	7.1	55	0.015	0.0012	0.007	0.006	0.048	0.0085	0.029	0.0007	0.013	0.0032	0.052
Minimum	6.3	30	0.003	0.0002	0.001	0.001	0.03	0.003	0.005	0.0002	0.01	0.001	0.01
Maximum	8.0	113	0.05	0.003	0.03	0.02	0.22	0.05	0.1	0.001	0.03	0.018	0.29
Region 3[2]													
Geometric Mean	4.3	439	0.005	0.0036	0.434	0.0037	0.225	0.0085	0.681	0.0008	0.098	0.0031	0.542
Minimum	3.4	254	0.003	0.0009	0.001	0.001	0.02	0.002	0.014	0.0002	0.01	0.001	0.03
Maximum	6.6	887	0.006	0.014	3.01	0.01	6.1	0.04	1.75	0.001	0.24	0.005	1.6
Montana Human Health Standards			0.018	0.005	1	0.1	0.3	0.015	0.05	0.00014	0.1	0.05	5

Notes:

ND = no data

(1) Data from Table B-1, Appendix B of the Draft Final Report for GSM Foundation Materials ARD Attenuation Column Study (Schafer & Associates, July 1994).

(2) See Attachment 1

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$$Q_1C_1 + Q_2C_2 = Q_dC_d$$

where Q = flow
C = concentration
1 = source 1 (ambient groundwater),
2 = source 2 (dump seepage),
d = downgradient result (mixed groundwater and dump seepage).

4.2.1 Conceptual Model and Input Parameters

The following conceptual model for groundwater flow beneath and downgradient of the West Waste Dump was used as a framework for mixing calculations:

- A portion of the annual precipitation occurring at the mine infiltrates both the east and west flanks of the waste rock dump, migrates through the unsaturated zone, and combines with the ambient groundwater flow beneath the dump.
- A percentage of the total dump seepage flux is captured in toe drains underneath the dumps and the remainder infiltrates to groundwater.
- The West Side Dump groundwater capture system captures 80 to 94% of the combined ambient/seepage groundwater flux on both the west and east flanks (Appendix L, EIS). This captured water is routed to the treatment system.
- The remaining 6 to 20% of the combined ambient/seepage groundwater flux continues downgradient of the capture wells and is further diluted by precipitation recharge. Downgradient groundwater quality is a function of the quality and quantity of combined ambient/seepage water and the dilution factor provided by precipitation.

The required input parameters for the mixing model are:

- Ambient groundwater quality and flux;
- Waste rock dump seepage water quality and flux; and
- Precipitation recharge rate (concentrations of the constituents of interest in precipitation recharge, including metals and sulfate, are assumed to be negligible (zero) for this mixing analysis).

Ambient Groundwater Quality - Groundwater quality near the east and west flanks of the West Waste Rock Dump was estimated from historical data for monitoring wells and springs in these areas. Sites used for the east flank were PW-3, PW-17, and Steppan Spring. Sites used for the west flank were PW-2, PW-13, PW-14, PW-15, PW-16, PW-21, PW-42, PW-46, and Arkose Spring. To arrive at a value for ambient water quality, geometric means were calculated for each well. An overall average was then calculated for the area by computing the geometric mean of the individual geometric means (i.e., the sulfate concentration for the east flank was estimated as the geometric mean of the geometric mean sulfate concentrations for PW-3, PW-17, and Steppan Spring).

Ambient Groundwater Flux - The flow rate of ambient groundwater from Bull Mountain has been estimated at approximately 1 gallon per minute (gpm) per 100 feet of width based on previous modeling analyses (GSM 1995 Hard Rock Mine Permitting Application). This flux rate was used as the base case for modeling mixing. Source area widths were determined from maps of the final reclaimed dump perimeter. The west flank width was estimated as 5,000 feet (resulting in a flux of 50 gpm), and the east flank width as 4,000 feet (40 gpm).

The ARD model used for assessing sulfate transport from the reclaimed dumps in the EIS (Appendix J) assumed a much lower ambient flux for the west side of Bull Mountain of 12 gpm. Mixing effects were also evaluated for this extremely low rate of flux to determine its effect on potential capture requirements.

Dump Seepage Water Quality - Water quality of dump seepage was estimated as the geometric mean of results from the analysis of five lysimeter samples (SM6-10, SM3-10, SM2-40, SM2-5, and SM1-10) installed to sample porewater in the West Waste Rock Dump (see Table 2-1, Summary of Porewater Quality Data).

Dump Seepage Flux -- Dump seepage estimates were obtained from Appendix J of the Draft EIS, and are based on 0.5 inches of infiltration per year. Total seepage estimates are 10 gpm for the west flank and 4 gpm for the east flank. GSM has assumed some of this seepage will collect in existing bedrock drainages due to the low permeability of the underlying bedrock and emerge as toe seeps at the base of the dumps. Toe drains are provided for in the water management plan to capture this seepage component and route it to the permanent treatment plant. In the groundwater mixing analysis, toe drains are assumed to capture 50% of the seepage, while 50% goes to groundwater. An additional case also was evaluated where 100% of the seepage reaches groundwater. Groundwater immediately downgradient of the waste rock dumps, including any dump seepage component, would be captured by wells also located at the toe of the waste rock dumps. Both capture scenarios were evaluated to define the capture rates necessary to meet water quality requirements under a range of potential seepage scenarios.

__Precipitation Recharge__ -- A precipitation recharge rate of 1.5 inches per year was assumed for the bedrock aquifer outside of the waste rock dumps (from Appendix J of the Draft EIS).

__Groundwater Capture System Efficiency__ -- The EIS (Appendix L) states that theoretical capture efficiencies of nearly 100 percent are possible provided that no major fracture systems are missed. Assuming 20 percent of the fractures are missed by the capture well system results in capture efficiencies from 80 to 94 percent. For purposes of assessing mixing a capture efficiency of 80 percent is conservatively assumed.

4.2.2 Mixing Calculation Results - The results of the groundwater mixing calculations are in Tables 4-2 and 4-3. Model assumptions and input parameters are also shown in the summary tables. Downgradient water quality was calculated at several different downgradient points for each flank. Total precipitation recharge varies for each point, depending on the amount of area over which precipitation contributes to groundwater dilution. The recharge areas are approximately equal to the distance downgradient from the waste rock dumps multiplied by the source width (5,000 feet for the west flank, and 4,000

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Table 4-2. Summary of West Dump Predicted Groundwater Concentrations – West Flank

A. Groundwater Flow and Mixing Zone Dimension Assumptions Used in Mixing Analysis

Ambient GW Flow (gpm)(1)	12	Mixing Zone Dimensions and Precipitation Recharge					
Total Dump Seepage (gpm)(2)	10	Proposed Permit Boundary		BLM Property Boundary		I-90 Area	
Dump Seepage to Toe Drain (gpm)(3)	5	Distance (ft)	1690	Distance (ft)	5556	Distance (ft)	15011
Net Dump Seepage to GW (gpm)(3)	5	Area (ft²)	11,271,600	Area (ft²)	26,672,400	Area (ft²)	82,275,647
Total GW Flow @ Capture Wells (gpm)(4)	17	Recharge (gpm)(6)	20.1	Recharge (gpm)	47.6	Recharge (gpm)	146.7
Net GW Flow After Capture Wells (gpm)(5)	3.4	Dilution Factor(7)	5.90	Dilution Factor	13.96	Dilution Factor	43.0

B. Predicted and Ambient Groundwater Quality vs. Distance from Waste Rock Dump

				Distance Downgradient 1690 ft		Distance Downgradient 5556 ft		Distance Downgradient 15011 ft			
				Proposed Permit Boundary Concentrations		BLM Property Boundary Concentrations		I-90 Area Concentrations			
Parameter	Ambient GW Concentration(8) (mg/L)	Dump Seepage Concentration(9) (mg/L)	Predicted Pumpback Well Concentration(10) (mg/L)	Mixing Zone Prediction (mg/L)	Ambient(8) (mg/L)	Mixing Zone Prediction (mg/L)	Ambient (mg/L)	Mixing Zone Prediction (mg/L)	Ambient(11) (mg/L)	Montana GW Quality Standards	Nonsignificance Limit(12)
sulfate	1011	30000	9537	5627	1011	683	↑	222	874		
arsenic	0.007	0.027	0.0129	0.0022	0.007	0.0009		0.0403	0.005	0.018	no change
cadmium	0.012	0.0179	0.0035	0.0009	0.002	0.0004		0.0001	0.001	0.005	0.0008
copper	0.01	9.18	2.706	0.459	0.01	0.196		0.0629	0.01	1	0.15
chromium	0.004	0.225	0.0690	0.0117	0.004	0.0049		0.0016	0.01	0.1	0.015
iron	2.36	55.52	17.33	2.96	2.36	1.28	NO DATA	0.403	0.49	0.3	0.03
lead	0.007	0.003	0.0038	0.0010	0.007	0.0004		0.0001	0.01	0.015	0.002
manganese	1.85	0.629	3.26	0.55	1.85	0.233		0.076	0.056	0.05	0.005
nickel	0.152	1.08	0.424	0.072	0.152	0.078		0.0099	nd	0.1	0.015
selenium	0.002	0.002	0.0023	0.0004	0.002	0.0002		[illegible]	0.001	0.05	0.0075
zinc	0.458	2.76	1.117	0.189	0.458	0.080		0.0260	0.025	5	0.75
NO_3+NO_2	0.169	0.11	0.152	0.03	0.169	0.031	↓	0.0035	0.156	10	7.5

NOTES:

(1) Assumes 1 gpm generated per 100 feet of width, and a source width of [illegible] ft.
(2) Based on DB "Expected" Case (0.5 inches infiltration per year).
(3) Assumes 50% capture of total dump seepage by toe drains.
(4) Based on ambient groundwater flow plus net dump seepage flux.
(5) Assumes 80% capture of mixed ambient groundwater and net dump seepage (20% continues downgradient).
(6) Based on 1.5 inches per year of infiltrating precipitation over mixing zone area.
(7) Dilution Factor = ratio of precipitation recharge to net groundwater flux after capture wells.
(8) Calculated from historic data for wells PW-2, -13, -14, -15, -16, -21, -42, -46, and [illegible] Spring.
(9) Calculated from waste rock dump lysimeter data (Table 2-1).
(10) Resultant water quality after mixing net dump seepage and ambient groundwater.
(11) Estimated from sample results for residential wells C. Davis, J. Davis, G. Buell (see Attachment 1).
(12) The "nonsignificance limit" represents the allowable concentration at a mixing zone boundary for a discharge to be nonsignificant.
The nonsignificance limits are calculated as 15% of the lowest applicable standard for toxic parameters, and 10% of the lowest applicable standard for harmful parameters.

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Table 4-3. **Summary of West Dump Predicted Groundwater Concentrations – East Flank**

A. Groundwater Flux and Mixing Zone Dimension Assumptions Used in Mixing Analysis

		Mixing Zone Dimensions and Precipitation Recharge					
		Current Permit Boundary		Property Boundary		I-90 Area	
Ambient GW Flux (gpm)(1)	40						
Total Dump Seepage (gpm)(2)	4						
Dump Seepage to Toe Drain (gpm)(3)	2	Distance (ft)	2625	Distance (ft)	5565	Distance (ft)	7467
Net Dump Seepage to GW (gpm)(4)	2	Area (ft²)	15,488,262	Area (ft²)	35,672,448	Area (ft²)	56,270,325
Total GW Flux @ Capture Wells (gpm)(4)	42	Recharge (gpm)(6)	24.4	Recharge (gpm)	56.5	Recharge (gpm)	89.4
Net GW Flux After Capture Wells (gpm)(5)	8.4	Dilution Factor(7)	2.90	Dilution Factor	6.73	Dilution Factor	10.6

B. Predicted and Ambient Groundwater Quality
vs. Distance from Waste Rock Dump

				Distance Downgradient: 2625 ft		Distance Downgradient: 5565 ft		Distance Downgradient: 7467 ft			
				Current Permit Boundary Concentrations		Property Boundary Concentrations		I-90 Area Concentrations			
Parameter	Ambient GW Concentration(8) (mg/L)	Dump Seepage Concentration(9) (mg/L)	Predicted Pumpback Well Concentration(10) (mg/L)	Mixing Zone Prediction (mg/L)	Background(11) (mg/L)	Mixing Zone Prediction (mg/L)	Background (mg/L)	Mixing Zone Prediction (mg/L)	Background(12) (mg/L)	Montana GW Quality Standards	Nonsignificance Limit(13)
sulfate	3710	30000	4962	1712	1903	760	▲	466	834		
arsenic	0.0068	0.027	0.0078	0.0027	0.0039	0.0012		0.0007	0.005	0.018	no change
cadmium	0.025	0.0139	0.0245	0.0086	0.0066	0.0036		0.0023	0.0041	0.005	0.0008
copper	0.106	9.18	0.538	0.186	0.008	0.080		0.0505	0.01	1	0.15
chromium	0.008	0.225	0.0183	0.0063	0.0027	0.0027		0.0017	0.01	0.1	0.015
iron	148	53.32	143.49	49.50	47.7	21.39	NO	13.478	6.69	0.3	0.03
lead	0.022	0.003	0.0211	0.0073	0.0455	0.0031	DATA	0.0020	0.01	0.015	0.002
manganese	15.8	0.629	15.06	4.64	4.89	2.066		1.264	0.056	0.05	0.005
nickel	2.46	1.08	2.394	0.826	0.562	0.357		0.2200	nd	0.1	0.015
selenium	0.0012	0.002	0.0012	0.0011	0.0022	0.0005		0.0003	0.005	0.05	0.0075
zinc	8.99	2.70	8.690	2.998	0.309	1.296		0.0165	0.025	5	0.75
NO_3+NO_2	0.098	0.11	0.099	0.03	0.067	0.015	▼	0.0093	0.156	10	7.5

NOTES:

(1) Assumes 1 gpm generated per 100 feet of width, and a source width of 4000 ft.
(2) Based on EIS "Expected" Case (0.5 inches infiltration per year).
(3) Assumes 50% capture of total dump seepage by toe drains.
(4) Based on ambient groundwater flux plus net dump seepage flux.
(5) Assumes 80% capture of mixed ambient groundwater and net dump seepage (20% continues downgradient).
(6) Based on 1.5 inches per year of infiltrating precipitation over mixing zone area.
(7) Dilution Factor = ratio of precipitation recharge to net groundwater flux after capture wells.
(8) Calculated from historic data for wells PW-3, -17, and Sapphire Spring.
(9) Calculated from waste rock dump lysimeter data.
(10) Resultant water quality after mixing net dump seepage and ambient groundwater.
(11) Calculated from historic data for Sapphire Spring (Original location).
(12) Estimated from sample results for residential wells (C. Davis, J. Davis, G. Reed) (see Attachment 3).
(13) The "nonsignificance limit" represents the allowable concentration at a mixing zone boundary for a discharge to be nonsignificant.
The nonsignificance limits are calculated as 15% of the lowest applicable standard for toxic parameters, and 10% of the lowest applicable standard for harmful parameters.

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feet for the east flank). Recharge areas, waste rock dumps, and downgradient groundwater quality calculation points are shown on Figure 4-1.

Based on the capture efficiency of 80 percent conservatively assumed for mixing calculations, all water quality standards and non-significance limits for all metals except copper are met at the BLM property boundary. The capture efficiency necessary to meet the non-significance limit for copper is approximately 85 percent, well within the range of capture efficiencies that are possible from the proposed groundwater capture system. Using the lower range assumption for ambient seepage of 12 gpm presented in the EIS ARD model for the west flank results in a three-fold increase in concentrations at the pumpback wells, but concentrations at the permit boundary and property boundary are essentially the same or lower than the base case due to the decrease in volume of water passing the capture wells and a corresponding increase in dilution by downgradient recharge. Alternatively, if all of the dump seepage mixes with groundwater (i.e. no toe drain capture), a higher rate of groundwater capture by pumpback wells (approximately 93%) would be required to meet water quality standards and non-significance limits at the mixing zone boundary.

The EIS (Appendix L) indicates that theoretical capture efficiencies of 100 percent are possible and that capture efficiencies of up to 94 percent may be realized even if 20 percent of the fractures are missed by the capture well system. Based on this analysis it is concluded that the proposed groundwater capture system is likely to result in compliance with groundwater quality standards and nondegredation limits at the proposed mixing zone boundary. As a contingency action, additional capture wells could be installed to achieve greater capture efficiency as needed.

Mixing zone calculations predict that groundwater quality near existing domestic supplies ("I-90 Area Concentrations" on Table 4-2) will remain similar to existing water quality. Mixing zone calculations for the east flank indicate that all water quality standards and non-significance limits are predicted to be met at the proposed permit boundary with the exception of the non-significance limit for copper. Although concentrations of cadmium, iron, manganese, and zinc are predicted to exceed Human Health Standards and/or non-significance limits at the permit boundary after groundwater capture, the resultant groundwater concentrations are predicted to be lower than existing concentrations. For the west flank, the groundwater capture system recovers more cadmium, iron, manganese, and zinc load than is released by the dump, resulting in a net improvement in groundwater quality. The predicted cadmium, iron, manganese, and zinc concentrations do not constitute degradation since there is no increase in concentrations and do not constitute violations of Human Health Standards since it is not necessary to treat to purer than natural (ARM 16.20.1803(1)(d) and MCA 75-5-303).

4.3 TREATMENT PLANT DISCHARGE

Treated water is to be discharged to a percolation pond located below Impoundment No. 2. Comparison of estimated treated water quality and ambient groundwater quality in the area is in Table 4-4. With the exceptions of sulfate and nitrate, concentrations of all other chemical parameters in treated water are similar to concentrations in ambient groundwater. Moreover, concentrations of all metal parameters are better than (lower than) Human Health Standards.

Nitrate concentration in treated water (5.7 mg/l) is higher than ambient groundwater, but less than the non-significance limit of 7.5 mg/l. GSM has included a contingency for nitrate removal in its treatment plant design if ever needed for compliance. Sulfate concentration in treated water (2,700 mg/l) is higher than ambient groundwater near the point of discharge (260 to 482 mg/l) and downgradient near the permit/property boundary (approximately 1,500 mg/l at proposed interim compliance monitoring well OW-2). The proposed compliance limit for sulfate at OW-2 is 2,000 mg/l (see, Section 5.2) based on maintenance of sulfate levels in existing downgradient domestic water supplies (see Attachment 1).

TABLE 4-4. COMPARISON OF TREATMENT PLANT DISCHARGE AND AMBIENT WATER QUALITY

	Concentrations (mg/l)																
	TDS	SO_4	NO3 + NO2-N	Al	As	Cd	Cr	Cu	Fe	Pb	Mn	Hg	Ni	Se	Ag	Zn
Treatment Plant Discharge																
pH 10$^{(1)}$	4120	3270	5.74$^{(2)}$	<0.05	0.001	<0.001	0.021	0.008	<0.05	0.001	<0.05	ND	<0.001	ND	ND	<0.05
pH 10.5$^{(1)}$	2710	2700	5.74$^{(2)}$	<0.05	0.001	<0.001	0.016	0.007	<0.05	<0.001	<0.05	ND	<0.001	ND	ND	<0.05
Ambient Groundwater Quality$^{(3)}$	1549	648	23.6	0.1	0.005	0.001	ND	0.018	0.03	0.01	0.012	ND	ND	ND	0.005	0.069
Montana Human Health Standards			10	None	0.018	0.005	0.1	1	0.3	0.015	0.05	0.00014	0.1	0.05	None	5

Notes:

(1) See Table 2-2.
(2) Source: EIS Appendix A.
(3) Estimated from data for wells downgradient of proposed percolation pond area: OW-2, OW-3, OW-5, and OW-7 (see Attachment 1).

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4.4 IMPOUNDMENT NO. 1

Detailed description of groundwater impacts resulting from historic seepage from the impoundment is provided in Section III.B.2.f of the EIS. Maximum concentrations of cyanide and nitrate in the seepage plume (third row of SPB wells) downgradient of the impoundment in 1996 were 30 mg/l and 10 mg/l, respectively (Golden Sunlight 1997). Present areal extent of the plume within the Bozeman Unit is generally limited to within 600 to 800 feet of the east and southeast flanks of the impoundment and near the property boundary along the axis of the lower Rattlesnake alluvial unit. Concentrations of cyanide beyond this plume are generally less than analytical detection limits of 0.005 mg/l.

Cyanide concentration within the saturated tailings of the impoundment are continuing to decrease due to natural degradation of cyanide. Because of this decline in cyanide concentrations within the impoundment and the reduction in seepage rates that will occur following reclamation of the impoundment, cyanide concentrations in groundwater are predicted to decline to below detection prior to closure. The proposed action will therefore result in cyanide concentrations that are lower than the concentrations currently present in groundwater. GSM has incorporated a short-term contingency for cyanide treatment in its treatment plant design, should cyanide continue to be detected in pumpback well water following the end of mining.

Even with the presence of sulfide minerals in tailings, tailing porewater is currently neutral to alkaline due to residual mill processing reagents and contains relatively low concentrations of most metals. Based on ARD generation in the pit and waste dumps, it is predicted that eventually the neutralization capacity of the tailings will be exhausted and tailing porewater will become typical of other ARD waters at the mine site such as pit water. A comparison of current metal concentrations in tailing water and predicted metal concentrations in pit water is given in Table 2-3. GSM will maintain several contingencies for control of ARD migration from the impoundment. These contingencies (see, EIS Appendix A for detailed descriptions) include:

- use of existing Buttress Dump underdrain or Rattlesnake groundwater interception system to eliminate groundwater inflows to the impoundment; and
- continued operation of existing pumpback wells downgradient of the impoundment with treatment of recovered water prior to discharge.

The upgradient and downgradient groundwater interception systems will ensure that ARD impacts are confined to the immediate vicinity of the impoundment (see Section IV.B.2.c of the EIS) within the proposed permit boundary and the proposed mixing zone boundary described in Section 5.0.

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5.0 PROPOSED MIXING ZONE BOUNDARIES

The delineation of mixing zones and proposed compliance points and limits at GSM is based on the following statutory guidance.

- "Mixing Zone" means an area where water quality standards may be exceeded (MCA 75-5-103(14)).
- "Mixing Zone" means a portion of an aquifer, where initial dilution of a discharge takes place, where water quality changes may occur, and where certain water quality standards may be exceeded (ARM 16.20.1802).

Specific restrictions for groundwater mixing zones are (ARM 16.20.1806):

- Human health based groundwater standards must not be exceeded beyond the boundaries of the mixing zone.
- No mixing zone is allowed if the zone of influence of an existing drinking water supply well will intercept the mixing zone.

Requirements are that mixing zones have (MCA 75-5-301(4)):

- the smallest practicable size;
- a minimum practicable effect on water uses; and
- definable boundaries.

General considerations for cumulative effects of multiple or overlapping mixing zones (ARM 16.20.1804(2)(h)).

- It is not necessary for industrial wastes, sewage, or other wastes to be treated to a purer condition than the natural condition of the receiving water. (ARM 16.20.1803(1)(d) and MCA 75-5-303).
- Estimated parameter levels in the mixing zone area will be calculated unless the department determines that monitoring is necessary due to the potential harm to the impacted water and its beneficial uses (ARM 16.20.1803(1)(e)).

The proposed mixing zone boundary for GSM is a portion of the permit/GSM property boundary downgradient of mine facilities as shown on Figure 5-1.

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The rationale for this boundary is:

- The mixing analyses presented in Section 4 demonstrate that for the proposed action, estimated groundwater parameter levels (concentrations) resulting from each of GSM's mine facilities will comply with human health standards and nondegradation requirements for metals within the proposed boundary.
- The proposed mixing zone boundary allows initial dilution and, particularly for the East Dump, allows enough area for water quality changes (neutralization and attenuation of ARD) to occur.
- No existing drinking water supply wells are present within the proposed mixing zone.
- The proposed mixing zone is the minimum practicable size necessary to allow efficient capture and treatment of West Dump seepage water and natural neutralization and attenuation of East Dump seepage water.
- The proposed mixing zone will have minimum practicable effect on water uses since no existing drinking water supply wells are present within the mixing zone and human health standards will be met at the proposed mixing zone boundary.
- The proposed mixing zone is a definable boundary, legal description of which is presented in GSM's Application for Operating Permit.
- Consideration of multiple or overlapping mixing zones is provided by the proposed compliance limits.

5.1 PROPOSED COMPLIANCE POINTS

Proposed compliance points are existing and proposed monitoring wells near the proposed mixing zone boundary. In some areas of the site, most notably the eastern portion of the permit boundary downgradient of the East Dump and the southwestern portion of the permit boundary downgradient of the West Dump, there are currently no monitoring wells in the vicinity of the proposed mixing zone boundary. GSM has committed to further hydrogeologic investigation of these areas to identify optimum monitoring sites and to aid in the design of groundwater capture systems if ever needed as contingencies for dump seepage (see EIS Appendix A). In addition, GSM has committed to construction of additional monitoring wells along the East and West Dump perimeters as part of the proposed long-term groundwater monitoring plan (Appendix A of the EIS). The information obtained in these efforts will be used to design an appropriate monitoring system for these areas. Final compliance monitoring locations will be identified and selected in consultation with MDEQ. Interim compliance monitoring locations at existing wells/springs include: PW-46, PW-22 and Steppan Original Spring in the Southwest permit area; OW-2 and OW-3 in the southeast permit area; and PW-45 in the eastern permit area. In addition Bunk House and Rattlesnake Springs in the Rattlesnake Gulch area are used by wildlife and will be monitored as well.

5.2 PROPOSED COMPLIANCE LIMITS

Proposed compliance limits are groundwater concentrations that will comply with Montana Human Health Standards and non-degradation requirements based on ambient groundwater quality at the compliance points. Golden Sunlight's proposed mixing zone boundary encompasses an area of widely variable geology and groundwater quality. Because of this variability, it is impossible to derive a single set of compliance limits that are appropriate and applicable for all of the groundwater within the mixing zone. Therefore, proposed compliance limits are narrative limits from which numeric compliance limits may be derived for all compliance points. Proposed compliance limits based on the Montana Water Quality Act (MCA 75-5-100 et seq.), Montana Nondegradation of Water Quality Rules (ARM 16.20.700 et seq.), and Montana Groundwater Quality Standards (ARM 16.20.1001 et seq.) are:

Metal parameters classified as "toxins" in Circular WQB-7 (Antimony, Barium, Cadmium, Chromium, Copper, Iron, Lead, Manganese, Nickel, Selenium, Thallium, Zinc)

- For ambient groundwater concentrations lower than 15 percent of the Human Health Standard; compliance limit is 15 percent of the Human Health Standard. That is, no significant change in water quality or degradation (ARM 16.20.712(1)(c)).
- For ambient groundwater concentrations higher than 15 percent of the Human Health Standard; compliance limit is ambient groundwater quality plus the trigger value

concentrations listed in Circular WQB-7. That is, no significant change in water quality or degradation (ARM 16.20.712(1)(c)).

- For all other ambient groundwater, it is not necessary to treat to purer than natural (ARM 16.20.1803(1)(d) and MCA 75-5-303).

Parameters classified as "carcinogens" or parameters with bioconcentration factors > 300 in Circular WQB-7 (Arsenic, Beryllium, and Mercury)

- Compliance limits are ambient groundwater concentrations. That is, no significant change in water quality (ARM 16.20.712(1)(b)).
- For all ambient groundwater's, it is not necessary to treat to purer than natural ((ARM 16.20.1803(1)(d) and MCA 75-5-303).

For Nitrate

- Compliance limit is 7.5 mg/l nitrate as N. That is, no significant change in water quality or degradation (ARM 16.20.712(1)(d)(i)).
- For all ambient groundwater's, it is not necessary to treat to purer than natural (ARM 16.20.1803(1)(d) and MCA 75-5-303)

For Cyanide

- Compliance Limit is the Human Health Standard of 0.2 mg/l.

For Sulfate

- Although it is recognized that elevated sulfate concentrations may impair the use of groundwater for domestic water supplies (i.e. drinking water), there is no numeric water quality standard for sulfate and sulfate is not considered harmful, toxic, carcinogenic, or bioaccumulating by MDEQ. The proposed sulfate compliance limits are based on protection of the existing drinking water beneficial use and the normal ranges of sulfate in aquifers near the GSM permit area that are existing drinking water supplies (see ambient water quality data for domestic water supplies in Attachment 1). The rationale for these limits is that by maintaining sulfate concentrations at the mixing zone boundary at current concentrations, protection of existing downgradient uses is assured. Proposed sulfate compliance limits are:

1.	Bozeman Unit - East Side	1,000 mg/l
2.	Jefferson Alluvium Unit	2,000 mg/l
3.	Bedrock - West Dump West Flank	1,500 mg/l
4.	Bedrock - West Dump East Flank	1,500 mg/l

For all ambient groundwater's, it is not necessary to treat to purer than natural ((ARM 16.20.1803(1)(d) and MCA 75-5-303)

5.3 IMPACTS TO WATER USES

No impacts to domestic water uses are expected to result from the proposed mixing zone. No existing drinking water supply wells are present within the proposed mixing zone and land and groundwater uses within the mixing zone are or will be wholly controlled by GSM. At the mixing zone boundary and beyond, ambient groundwater quality will be maintained under this plan.

Steppan Original, Bunk House, and Rattlesnake Spring are used by wildlife and potentially could experience reduced water quality due to waste rock seepage. Based on mixing cell-modeling of dump seepage's, impacts at these springs could range from minor water quality changes with no associated impact on use, to more severe water impacts that could limit wildlife use. Discharges from these springs are small and typically range from less than 1 to 5 gpm from each spring. GSM proposes to mitigate these potential impacts by monitoring and, if necessary, replacement of these wildlife uses with alternative water sources of similar quantity and quality.

6.0 COMPLIANCE MONITORING PLAN

Groundwater monitoring at GSM has two primary goals:

- to provide early detection of any emerging water quality changes so that mitigation actions can be taken, if necessary; and
- to provide water quality information necessary to evaluate compliance with applicable water quality regulations.

To meet the first goal of early detection of water quality changes, GSM currently monitors water quality at over 125 sites within and near the GSM facility. Under GSM's long-term monitoring plan (Appendix A of EIS), over 80 wells and springs will be monitored quarterly during operations and after mine closure. Monitoring would be conducted until such time that it is no longer required by MDEQ and BLM. The monitoring plan describes the following course of action if data indicates that water quality changes are occurring within the proposed mixing zone boundary:

1. Verify water quality change.
2. Notify MDEQ and BLM as to change in water quality conditions.
3. As appropriate, implement mitigation as described in EIS Appendix A.

The following proposed modifications to GSM's current monitoring plan specifically address the methods that will be used to demonstrate compliance with the proposed mixing zone boundary and groundwater quality compliance limits (i.e., the applicable water quality regulations). Upon approval by MDEQ, the compliance monitoring changes would be incorporated into GSM's long-term monitoring plan (EIS, Appendix A). As described in Section 5.1, proposed interim compliance monitoring locations are wells/springs: PW-46, PW-22 and Steppan Original Spring in the southwest permit area; OW-2 and OW-2 and OW-3 in the southeast permit area; and PW-45 in the eastern permit area. As stated in GSM's monitoring plan, these monitoring locations are sampled two to four times annually for general water quality (chemical) parameters including cyanide and selected metals at selected monitoring locations. For mixing zone compliance, the proposed plan will be to monitor these locations four times annually for general water quality parameters and all metals for which Human Health Standards are established in Circular WQB-7. The proposed Compliance Monitoring Plan is summarized in Tables 6-1 and 6-2.

GSM has committed to further hydrogeologic investigations to determine optimum monitoring locations and to evaluate the design of groundwater capture systems as contingencies for dump seepage (see EIS Appendix A). In addition, GSM has committed to construct additional monitoring wells along the dump perimeters as part of the long-term monitoring plan (Appendix A of the EIS). A final mixing zone compliance monitoring plan will include additional wells along the approved mixing zone boundaries, as identified in consultation with MDEQ.

TABLE 6-1 PROPOSED INTERIM COMPLIANCE MONITORING LOCATIONS

MONITORING WELLS*	SPRINGS
PW-22	Steppan Original Spring
PW-[illegible]	Buck House Spring
PW-46	Rattlesnake Spring
OW-2	
OW-3	

* New wells to be added pending DEQ Approval of mixing zones.

TABLE 6-2 COMPLIANCE MONITORING PARAMETER LIST

Common Ions and Nutrients	Trace Metals	Trace Metal Detection Limits (mg/l)
Total Dissolved Solids	Aluminum	0.1
pH	Antimony	0.003
Calcium	Arsenic	0.003
Sodium	Barium	0.005
Magnesium	Beryllium	0.001
Potassium	Cadmium	0.0001
Total Hardness as $CaCO_3$	Chromium	0.001
Total Alkalinity as $CaCO_3$	Copper	0.001
Total Acidity as $CaCO_3$	Iron	0.01
Fluoride	Lead	0.003
Sulfate	Manganese	0.005
Chloride	Mercury	0.0006
Ammonia as N	Nickel	0.02
Nitrate as N	Selenium	0.001
Specific Conductivity	Silver	0.003
	Thallium	0.002
	Zinc	0.01

Notes:

Waters to be analyzed for dissolved metals.

Trace metal detection limits based on Required Reporting Values in Circular WQB-7, December, [illegible]

7.0 CONTINGENCY PLAN

Based on available information, water quality in the GSM project area is expected to meet the compliance limits at the proposed mixing zone boundary. GSM also has developed plans for additional water protection practices that would be implemented if monitoring data indicate that constituents would migrate beyond the mixing zone at concentrations greater than the proposed compliance limits. These contingency actions are detailed in GSM's long-term water management plan (Appendix A of EIS), and include the following:

West Waste Dump Groundwater Capture System. Capture wells and/or toe drains would be used to control the migration of impacted groundwater. The intercepted groundwater would be treated in the permanent water treatment plant prior to discharge.

Continued Operation of Impoundment No. 1 Pumpback System. Intercepted groundwater and tailings seepage would be treated prior to discharge.

Impoundment No. 2 Pumpback Contingency. Existing pumpback wells provide contingency for recovery of groundwater for treatment if needed.

East Waste Rock Dump Groundwater Capture Contingency. Similar to the west side system, capture wells or toe drains would be used as a contingency to control the migration of impacted groundwater. The intercepted groundwater would be treated in the permanent water treatment plant prior to discharge.

Expanded Water Treatment Contingency. The water treatment plant could be expanded to meet the water handling requirements of contingency actions which result in increased flows to the treatment plant. In addition, contingency plans have been developed for treatment of cyanide and nitrate, if treatment of these parameters is necessary in addition to the planned treatment for acidity and metals.

8.0 REFERENCES

Hydrometrics. 1997a. Long-Term Water Management at GSM. In Appendix A of GSM EIS.

Hydrometrics. 1997b. Design and Estimated Costs for Water Treatment Plant at Golden Sunlight Mines, Inc.. In Appendix A of GSM EIS.

GSM. 1995. Hard Rock Mining Permit Application and Plan of Operations for Amendment to Operating Permit 00065.

GSM. 1997. Golden Sunlight Mine Annual Permit Report, 1996.

Schafer. 1994. Draft Final Report for GSM Foundation Materials ARD Attenuation Column Study, July 1994.

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ATTACHMENT 1

AMBIENT GROUNDWATER QUALITY DATA AND STATISTICS

A) Groundwater Region 1A

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Golden Sunlight Mines, Inc.
Groundwater Region 1A (East of No. 2 Impoundment)
Ambient Groundwater Quality

Parameter	Geometric Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)
pH (field)	7.1	5.8	8.5
TDS	382	3.6	650
sulfate	[illegible]	42	234
NO_3+NO_2	0.48	0.01	19.1
aluminum	0.1	0.1	0.1
antimony	0.0039	0.003	0.005
arsenic	0.024	0.003	0.132
barium	0.043	0.019	0.1
beryllium	0.001	0.001	0.001
cadmium	0.0003	0.0001	0.001
copper	0.004	0.001	0.01
chromium	0.0012	0.001	0.002
iron	0.02	0.005	0.03
lead	0.0026	0.002	0.003
manganese	0.012	0.005	0.096
mercury	0.0005	0.0002	0.0006
nickel	0.014	0.01	0.02
selenium	0.0022	0.001	0.025
silver	0.002	0.0005	0.003
thallium	0.0028	0.002	0.003
zinc	0.046	0.02	0.1

NOTES: (for following tables)

Historic data for EGW-4, EGW-5, MW-209, MW-210, and GW-52 used in calculations.

Water quality values calculated as follows:

(1) summary statistics were calculated for individual wells.

(2) overall regional statistics calculated using summary statistics for each well (i.e., geometric mean in table = geometric mean of the geometric means for individual wells EGW-4, EGW-5, MW-209, MW-210, and GW-52).

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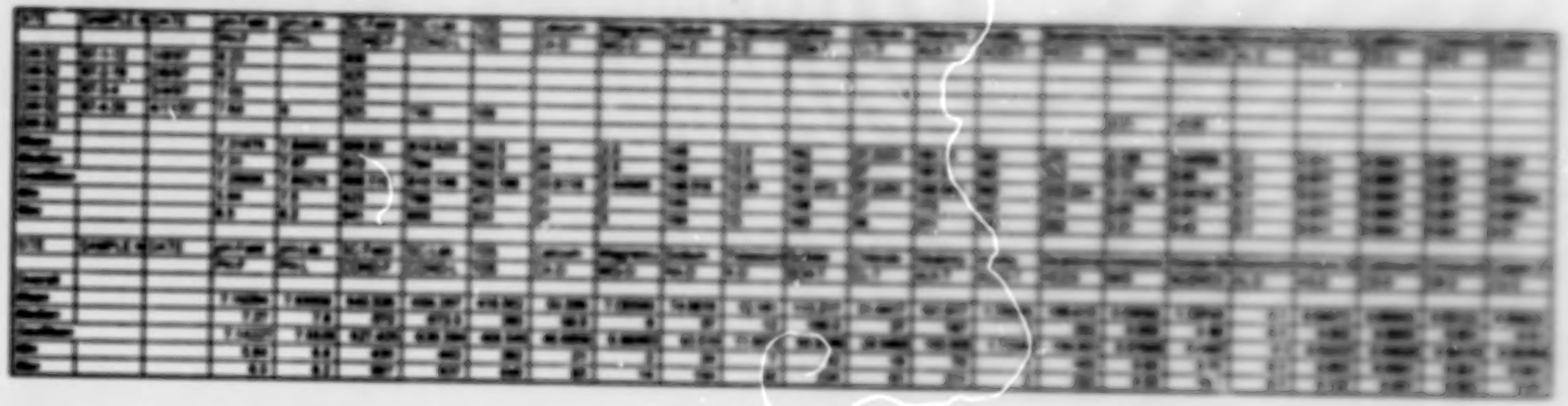

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B) Groundwater Region IB

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Golden Sunlight Mines, Inc.
Groundwater Region 1B (East of Mine Pit)
Ambient Groundwater Quality

Parameter	Geometric Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)
pH (field)	7.1	6.3	8.0
TDS	318	227	423
sulfate	55	30	113
NO_3+NO_2	0.63	0.05	1.85
aluminum	0.1	0.1	0.1
antimony	0.0034	0.003	0.005
arsenic	0.015	0.003	0.05
barium	0.068	0.018	0.1
beryllium	0.001	0.001	0.001
cadmium	0.0012	0.0002	0.003
copper	0.007	0.001	0.03
chromium	0.006	0.001	0.02
iron	0.046	0.03	0.22
lead	0.0065	0.002	0.05
manganese	0.029	0.005	0.1
mercury	0.0007	0.0002	0.001
nickel	0.013	0.01	0.03
selenium	0.0032	0.001	0.018
silver	0.004	0.003	0.005
thallium	0.003	0.003	0.003
zinc	0.052	0.01	0.29

NOTES:
Historic data for PW-5, PW-8, PW-10, PW-18, PW-19, PW-42, and PW-45 used in calculations.
Water quality values calculated as follows:
(1) summary statistics were calculated for individual wells.
(2) overall regional statistics calculated using summary statistics for each well
(i.e., geometric mean in table = geometric mean of the geometric means for
each individual well.)
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C) Groundwater Region 2A

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Golden Sunlight Mines, Inc.
Groundwater Region 2A (South of SPB Well Area)
Ambient Groundwater Quality

Parameter	Geometric Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)
pH (field)	7.1	6.4	8.3
TDS	879	370	3050
sulfate	437	279	594
NO_3+NO_2	0.21	0.01	10.7
aluminum	0.094	0.01	0.3
antimony	0.004	0.003	0.005
arsenic	0.009	0.005	0.018
barium	0.024	0.014	0.1
beryllium	0.001	0.001	0.001
cadmium	0.001	0.0001	0.07
copper	0.013	0.001	0.18
chromium	0.0012	0.001	0.002
iron	0.054	0.005	2.8
lead	0.005	0.002	0.02
manganese	0.041	0.01	0.27
mercury	0.0006	0.0002	0.001
nickel	0.018	0.01	0.53
selenium	0.004	0.001	0.26
silver	0.0025	0.0005	0.005
thallium	0.0024	0.002	0.003
zinc	0.048	0.01	1.78

NOTES:
Historic data for GW-2A, GW-5, GW-23, GW-24, GW-38, and GW-51 used in calculations.
Water quality values calculated as follows:
(1) summary statistics were calculated for individual wells.
(2) overall regional statistics calculated using summary statistics for each well
(i.e., geometric mean in table = geometric mean of the geometric means for each individual well.)
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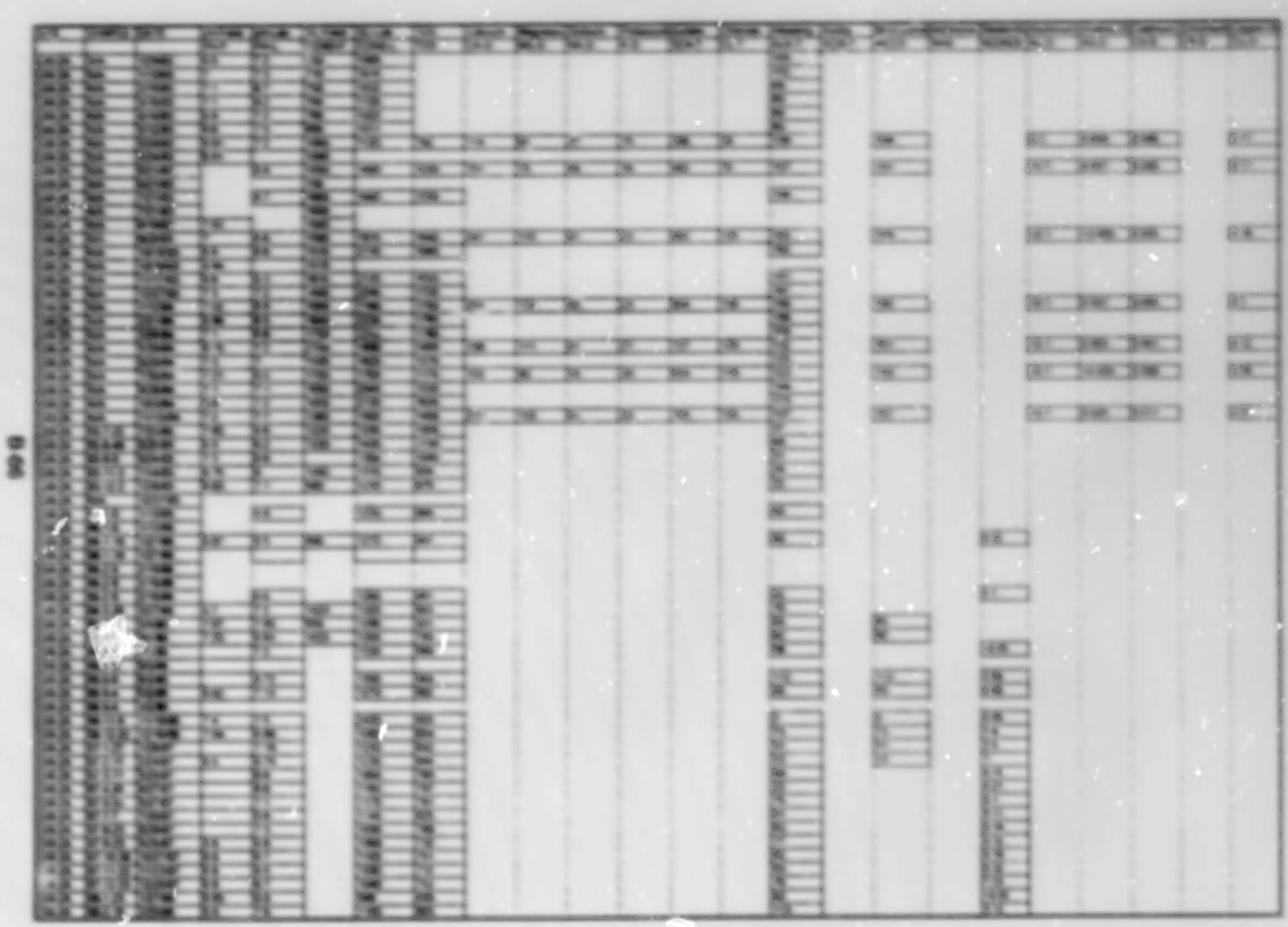

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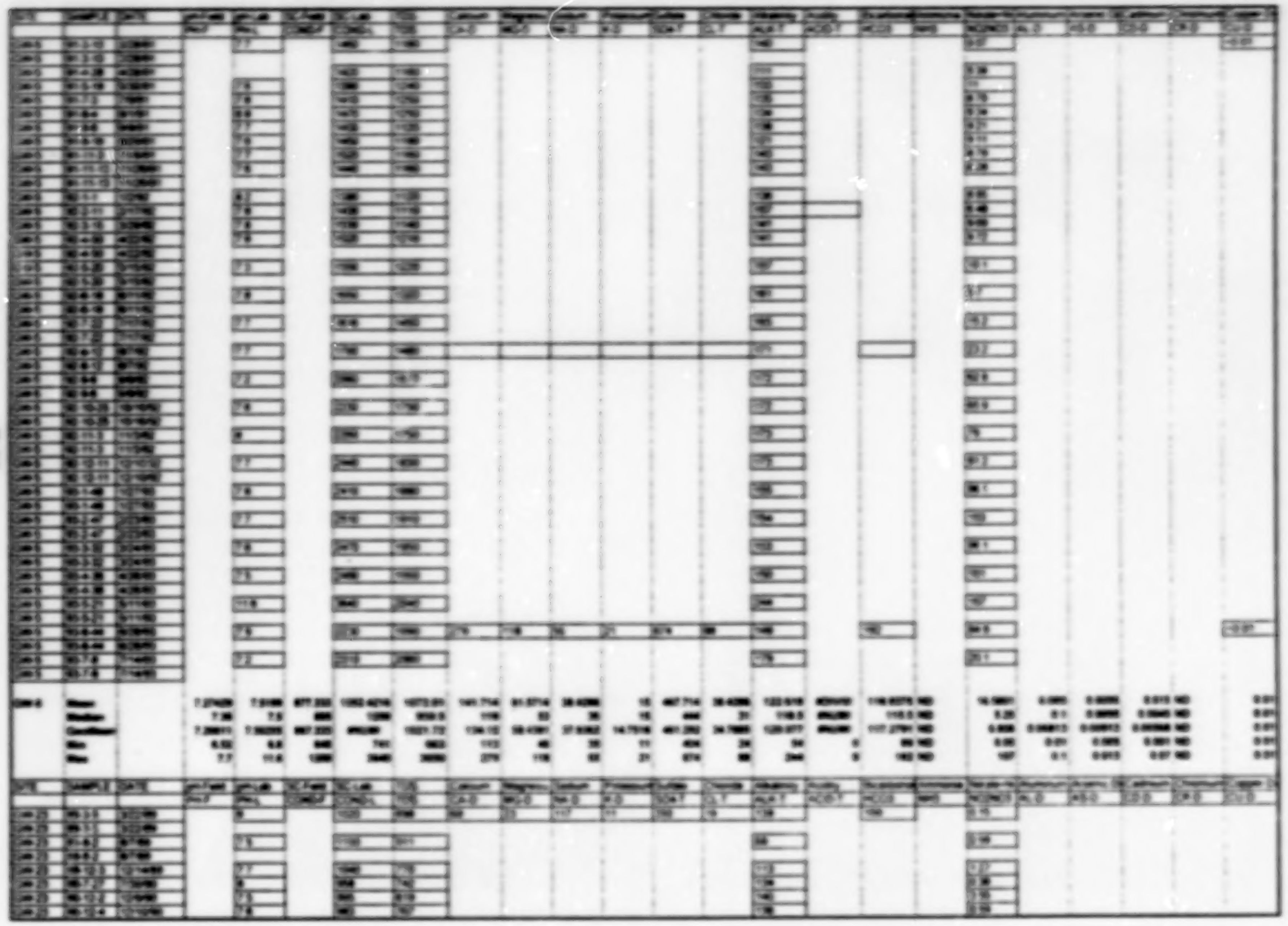

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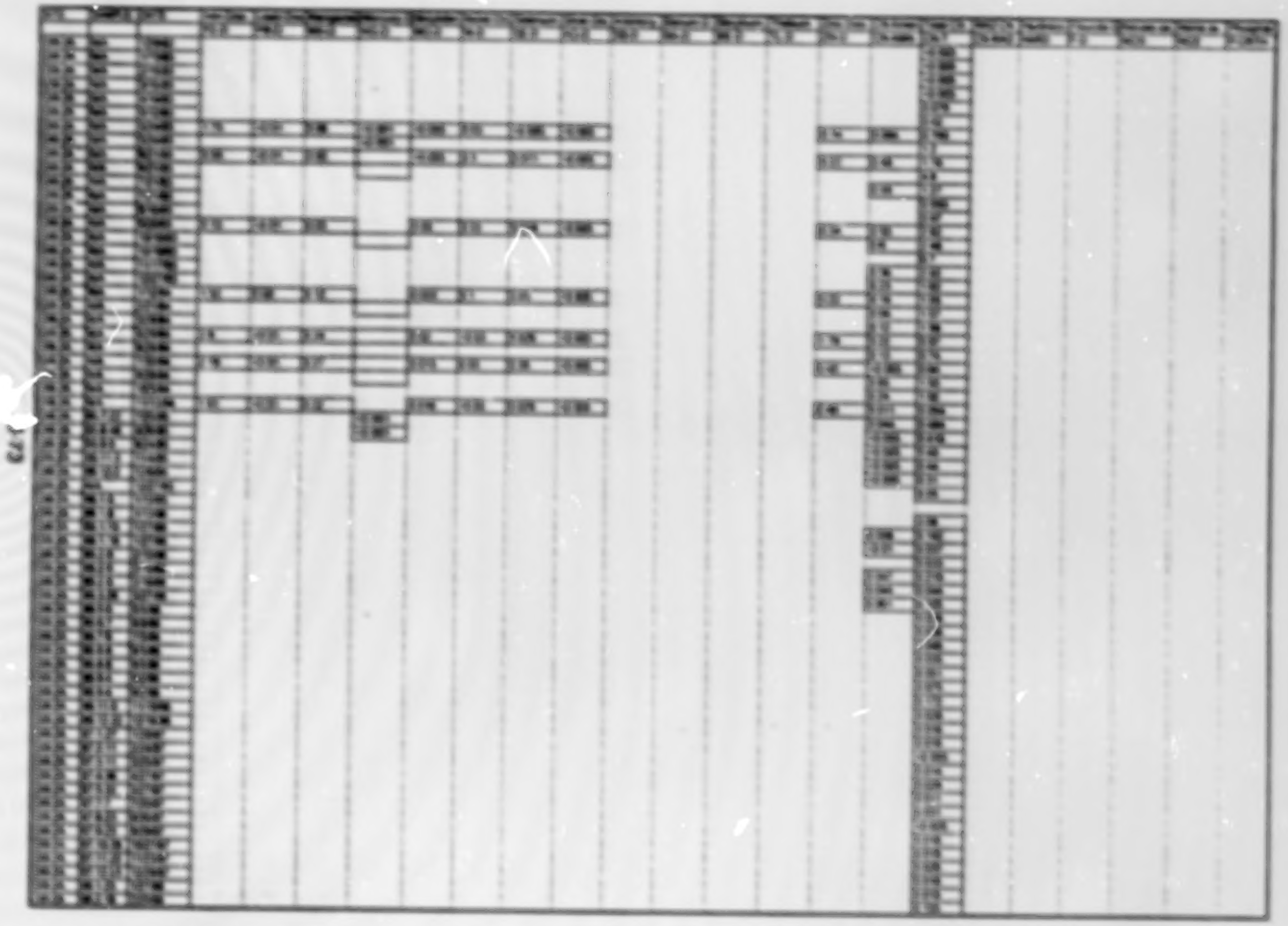

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D) Groundwater Region 2B

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Golden Sunlight Mines, Inc.
Groundwater Region 2B (South of No. 2 Tailings Pumpback Area)
Ambient Groundwater Quality

Parameter	Geometric Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)
pH (field)	7.2	5.8	8.2
TDS	578	372	2200
sulfate	260	182	482
NO_2+NO_3	0.29	0.05	44.8
aluminum	0.1	0.1	0.1
antimony	0.005	0.005	0.005
arsenic	0.013	0.013	0.013
barium	0.066	0.066	0.066
beryllium	0.001	0.001	0.001
cadmium	0.0002	0.0002	0.0002
copper	0.006	0.001	0.01
chromium	0.001	0.001	0.001
iron	0.023	0.005	0.08
lead	0.002	0.002	0.002
manganese	0.005	0.005	0.005
mercury	0.0002	0.0002	0.0002
nickel	0.011	0.01	0.02
selenium	0.004	0.004	0.004
silver	0.0005	0.0005	0.0005
thallium	0.002	0.002	0.002
zinc	0.037	0.02	0.05

NOTES:

Historic data for EGW-1, EGW-7D, EGW-7S, GW-57, and GW-62 used in calculations.

Water quality values calculated as follows:

(1) summary statistics were calculated for individual wells;

(2) overall regional statistics calculated using summary statistics for each well (i.e., geometric mean in table = geometric mean of the geometric means for each individual well.)

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E) Groundwater Region 3

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Golden Sunlight Mines, Inc.
Groundwater Region 3 (Southeast of Mine Pit -- Rattlesnake Drainage)
Ambient Groundwater Quality

Parameter	Geometric Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)
pH (field)	4.3	3.4	6.6
TDS	731	419	1360
sulfate	439	254	887
NO_2+NO_3	0.56	0.01	2.54
aluminum	6.5	0.1	92.5
antimony	0.003	0.002	0.005
arsenic	0.005	0.003	0.006
barium	0.054	0.008	0.1
beryllium	0.0028	0.001	0.005
cadmium	0.0036	0.0009	0.014
copper	0.434	0.001	3.01
chromium	0.0037	0.001	0.01
iron	0.225	0.02	6.1
lead	0.0085	0.002	0.04
manganese	0.681	0.014	1.75
mercury	0.0008	0.0002	0.001
nickel	0.098	0.01	0.24
selenium	0.0031	0.001	0.005
silver	0.0042	0.0005	0.005
thallium	0.003	0.002	0.004
zinc	0.542	0.03	1.6

NOTES:

Historic data for MW-200, MW-201, MW-202, PW-11, and Rattlesnake Spring used in calculations.

Water quality values calculated as follows:

(1) summary statistics were calculated for individual sites;

(2) overall regional statistics calculated using summary statistics for each site (i.e., geometric mean in table = geometric mean of the geometric means for individual sites).

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F) Groundwater Region 4A

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Golden Sunlight Mines, Inc.
Groundwater Region 4A (Southwest of No. 1 Tailings Impoundment)
Ambient Groundwater Quality

Parameter	Geometric Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)
pH (field)	6.9	6.1	8.4
TDS	1153	416	4440
sulfate	390	76	984
NO_2+NO_3	0.21	0.05	0.56
aluminum	0.112	0.1	0.2
antimony	0.003	0.003	0.003
arsenic	0.007	0.005	0.009
barium	0.058	0.034	0.1
beryllium	0.001	0.001	0.001
cadmium	0.0005	0.0001	0.001
copper	0.0089	0.001	0.04
chromium	0.004	0.001	0.02
iron	0.04	0.01	0.27
lead	0.007	0.003	0.01
manganese	0.035	0.005	0.27
mercury	0.0009	0.0006	0.001
nickel	0.011	0.01	0.03
selenium	0.005	0.005	0.005
silver	0.0044	0.003	0.005
thallium	0.003	0.003	0.003
zinc	0.04	0.01	0.07

NOTES:

Historic data for GW-10, GW-11, GW-38, GW-55, and GW-56 used in calculations.

Water quality values calculated as follows:

(1) summary statistics were calculated for individual sites.

(2) overall regional statistics calculated using summary statistics for each site (i.e., geometric mean in table = geometric mean of the geometric means for individual sites).

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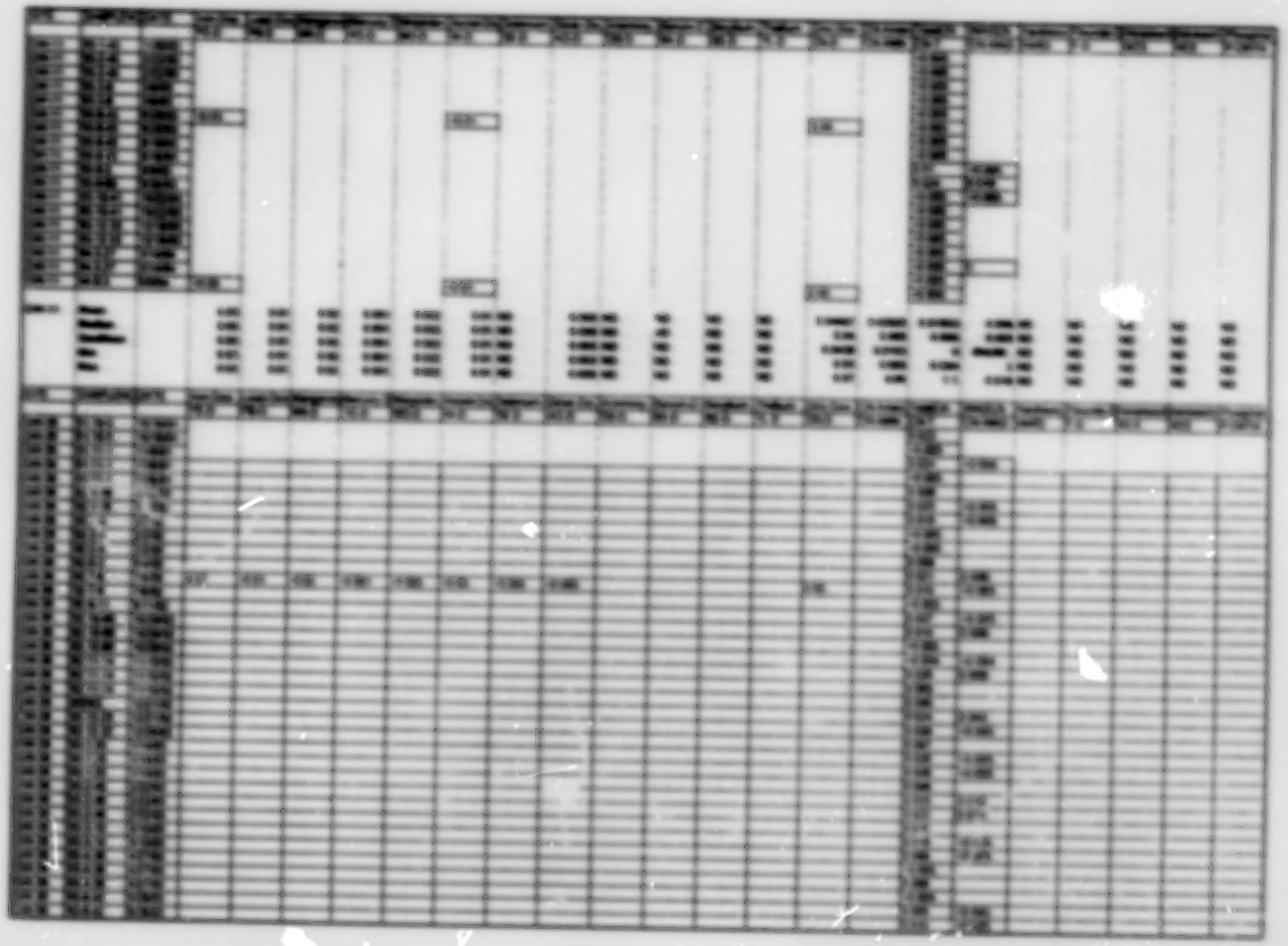

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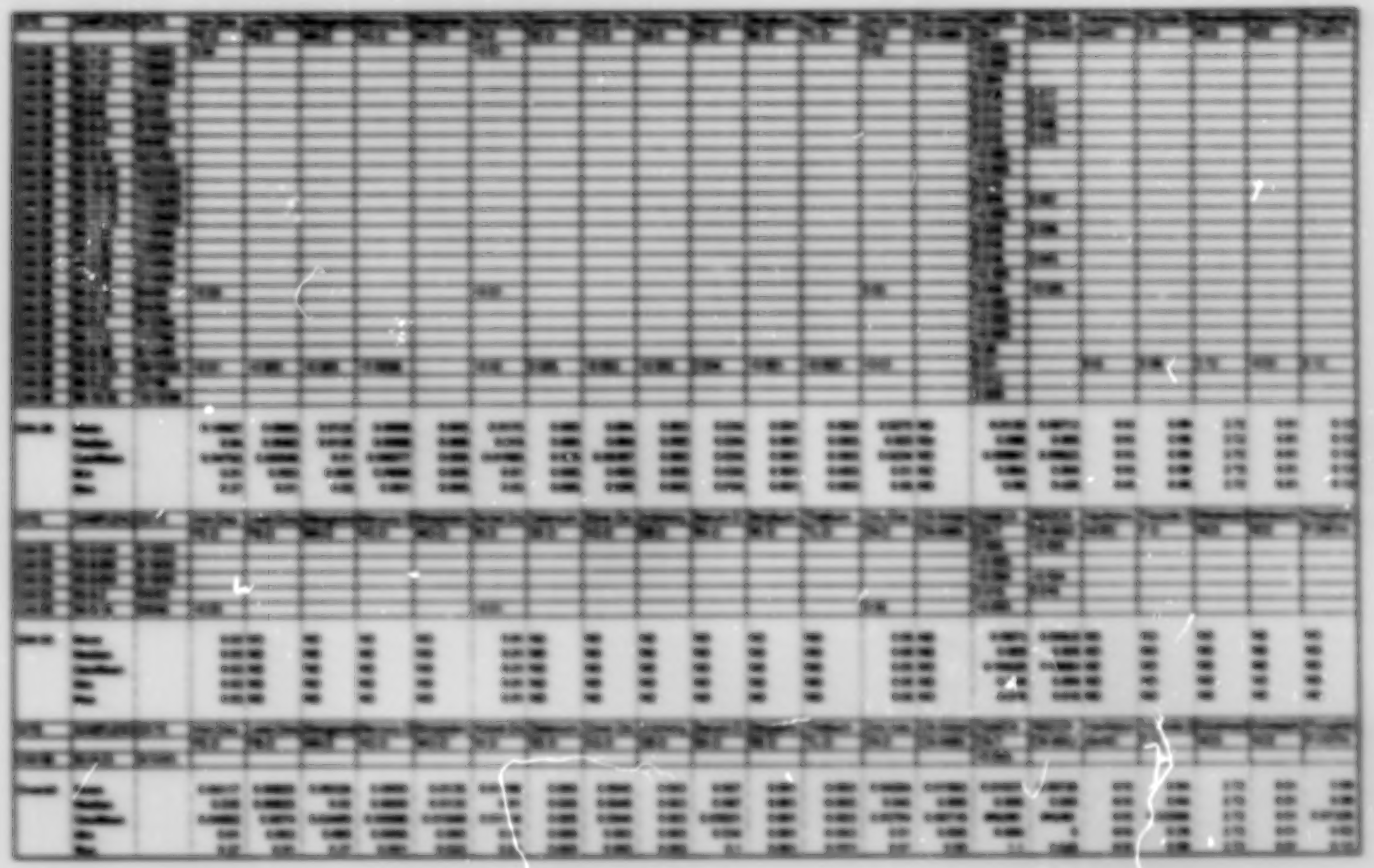

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G) Groundwater Region 4B

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Golden Sunlight Mines, Inc.

Groundwater Region 4B (West of No. 1 Tailings Impoundment)

Ambient Groundwater Quality

Parameter	Geometric Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)
pH (field)	7	6.2	8
TDS	995	621	1640
sulfate	345	112	718
NO_3+NO_2	0.28	0.01	13.1
aluminum	0.108	0.1	0.2
antimony	0.0039	0.002	0.005
arsenic	0.004	0.003	0.005
barium	0.042	0.005	0.1
beryllium	0.001	0.001	0.001
cadmium	0.0004	0.0001	0.003
copper	0.0067	0.001	0.04
chromium	0.0013	0.001	0.002
iron	0.039	0.02	1.28
lead	0.0034	0.003	0.01
manganese	0.084	0.01	0.361
mercury	0.0006	0.0006	0.001
nickel	0.017	0.01	0.03
selenium	0.0012	0.001	0.005
silver	0.0032	0.003	0.005
thallium	0.003	0.003	0.003
zinc	0.038	0.01	0.27

NOTES:

Historic data for GW-21, GW-39, and PW-22 used in calculations.

Water quality values calculated as follows:

(1) summary statistics were calculated for individual sites;

(2) overall regional statistics calculated using summary statistics for each site (i.e., geometric mean in table = geometric mean of the geometric means for individual sites).

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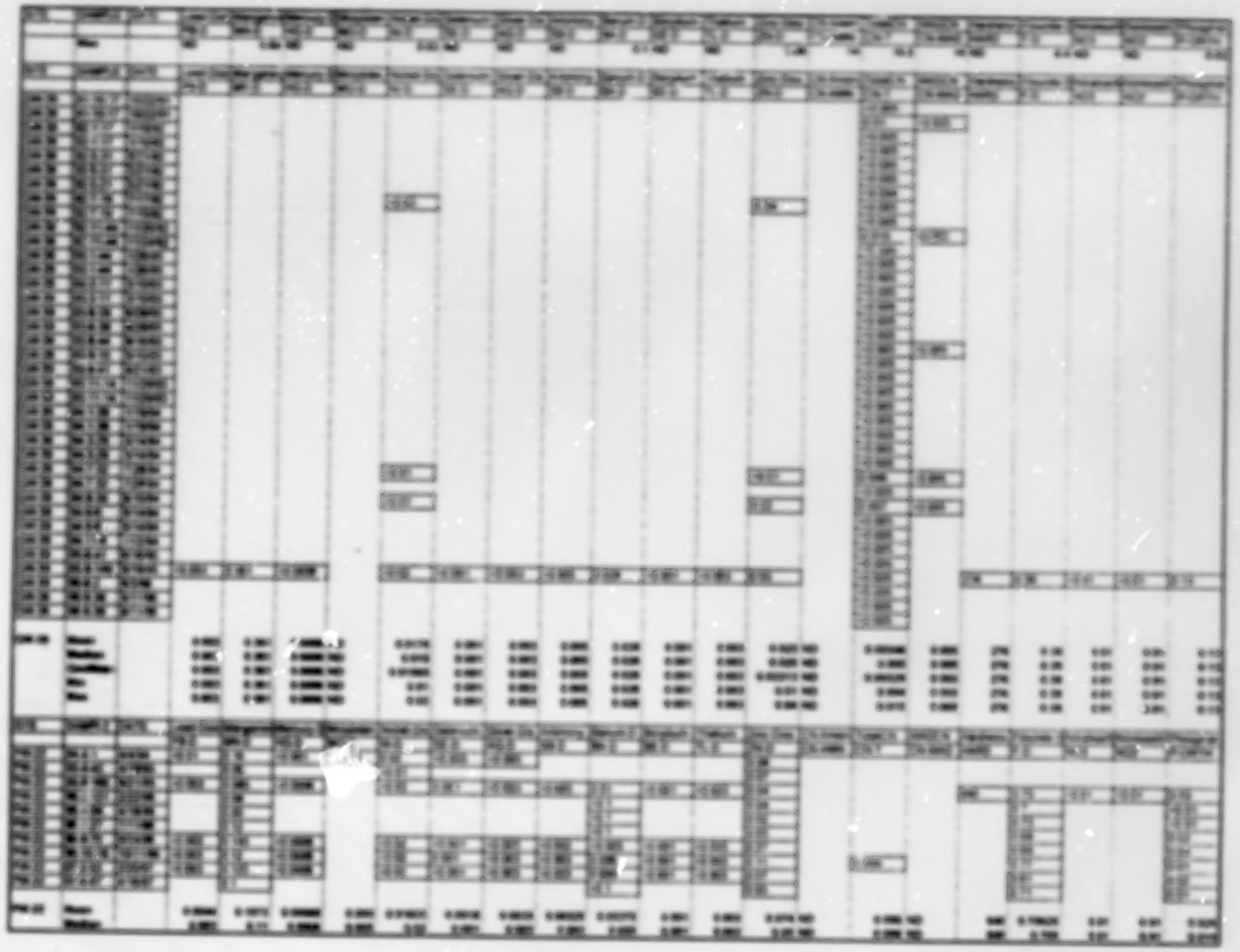

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SITE	SAMPLE	DATE	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	CoeffVar		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ND	[illegible]	ND	[illegible]	[illegible]	0.01	0.01	[illegible]
	Min		[illegible]	[illegible]	[illegible]	[illegible]	0.01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ND	[illegible]	ND	[illegible]	[illegible]	0.01	0.01	[illegible]
	Max		0.01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.1	[illegible]	[illegible]	0.27	ND	[illegible]	ND	[illegible]	0.77	0.01	0.01	[illegible]
Overall	Mean		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12	[illegible]	[illegible]	[illegible]	[illegible]	0.01	0.01	[illegible]
	Median		[illegible]	0.11	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	12	[illegible]	[illegible]	[illegible]	[illegible]	0.01	0.01	[illegible]
	CoeffVar		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.01	0.01	[illegible]
	Min		[illegible]	0.01	[illegible]	[illegible]	0.01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.01	0.01	[illegible]
	Max		0.01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.1	[illegible]	[illegible]	0.27	14	[illegible]	14	[illegible]	0.77	0.01	0.01	[illegible]

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H) Groundwater Wells Southeast of Project Site

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Golden Sunlight Mines, Inc.
Groundwater Wells – Southeast of Project Site
Ambient Groundwater Quality

Parameter	Geometric Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)
pH (field)	6.9	5.85	7.9
TDS	1365	12	4200
sulfate	600	48	1850
NO_2+NO_3	3.5	0.05	207
aluminum	0.1	0.1	0.1
antimony	nd	nd	nd
arsenic	0.005	0.005	0.007
barium	nd	nd	nd
beryllium	nd	nd	nd
cadmium	0.001	0.001	0.001
copper	0.015	0.01	0.11
chromium	0.02	0.02	0.02
iron	0.078	0.003	0.73
lead	0.01	0.01	0.01
manganese	0.047	0.02	0.18
mercury	0.001	0.001	0.001
nickel	0.014	0.01	0.03
selenium	0.006	0.005	0.01
silver	0.005	0.005	0.005
thallium	nd	nd	nd
zinc	0.051	0.01	1.56

NOTES:

Historic data for L FEIGHT, HM EG, KEBS, JCT 69, SM/SEN, GEO MC, SH-2, JEFF VET C, HMUL used in calculations.

Water quality values calculated as follows:

(1) summary statistics were calculated for individual sites;

(2) overall regional statistics calculated using summary statistics for each site (i.e., geometric mean in table = geometric mean of the geometric means for individual sites).

nd = no data for this parameter.

Below detect values replaced by the detection limit for calculations.

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SITE	SAMPLENO	DATE	pH-Field	pH-Lab	SC-Field	SC-Lab	TDS	Calcium	Magnesiu	Sodium	Potassium	Sulfate	Chloride	Alkalinity	Acidity	Bicarbonate	Ammonia	Nitrate+Ni	Aluminum	Arsenic D	Cadmium	Chromium	Copper D
[illegible]	88-1-6	1/15/88		7.2		1520	1180							183				28.8					
[illegible]	88-3-27	3/24/88																					
[illegible]	89-2-21	2/21/89		7.8		1710	1280							225				32					
[illegible]	89-6-26	6/23/89		7.9		1780	1300							237				35					
[illegible]	89-7-19	7/17/89																					
[illegible]	89-7-C	7/25/89																					
[illegible]	89-11-6	11/15/89																32					
[illegible]	90-6-10	6/18/90																34					
[illegible]	90-8-6	8/2/90																					
[illegible]	90-12-6	12/17/90																					
[illegible]	91-10-16	10/25/91						276	103	115	16.7	730	115	186		186							
[illegible]	92-4-54	4/24/92		7.8		2370	1890	261	111	108	13	662	129	222		271		43					
[illegible]	92-7-38	7/27/92																					
[illegible]	92-10-16	10/13/92		7.7		2400	1920	301	113	124	16	776	133	227		277		62					
[illegible]	93-1-29	1/12/93		7.7		2380	1970	312	117	116	17	802	142	219		267		63.3					
[illegible]	93-4-28	4/16/93		7.6		2430	2003	291	112	131	19	797	143	212		259		67.8					
[illegible]	93-7-34	7/27/93		7.5		2560	1990	276	108	132	19	775	140	214		261		59.4					
[illegible]	93-10-17	10/12/93		7.4		2470	2060	276	109	140	19	749	142	219		267		65.5					
[illegible]	94-1-15A	1/5/94		7.8		2670	2000	10	3	627	7	752	150	227		277							
[illegible]	94-4-4	4/5/94		7.7		2520	2020	302	103	135	18	721	146	226		275		69.7					
[illegible]	94-7-14	7/14/94		8.1		2450	2060	273	110	149	19	742	144	246		300		54.2					<0.01
[illegible]	94-10-63	10/5/94																38.5					
[illegible]	95-1-5	1/10/95	6.95	8.1	2110	2250	1810											46.7					
[illegible]	95-2-23	2/28/95																					
[illegible]	95-3-37	3/15/95	6.85		2250													43.4					
[illegible]		Mean	7.03667	7.71538	1726.67	2263.85	1686.92	257.4	98.9	177.7	16.77	768.1	138.3	217.923	ND	264	0.1	31.1862	ND	ND	ND	ND	0.01
		Median	6.95	7.7	2110	2400	1970	289	108.5	131.5	18.35	761	142	219	ND	269	0.1	38.8	ND	ND	ND	ND	0.01
		GeoMean	7.03429	7.71148	1673.11	2208.9	1775.96	201.273	76.3884	140.168	16.1052	777.883	137.831	217.32	ND	263.608	0.1	19.8084	ND	ND	ND	ND	0.01
		Min	6.85	7.2	820	1520	1180	10	3	108	7	721	115	183	ND	186	0.1	0.05	ND	ND	ND	ND	0.01
		Max	7.28	8.1	2250	2670	2080	312	117	627	19	862	150	246	ND	300	0.1	69.8	ND	ND	ND	ND	0.01

SITE	SAMPLENO	DATE	pH-Field	pH-Lab	SC-Field	SC-Lab	TDS	Calcium	Magnesiu	Sodium	Potassium	Sulfate	Chloride	Alkalinity	Acidity	Bicarbonate	Ammonia	Nitrate+Ni	Aluminum	Arsenic D	Cadmium	Chromium	Copper D
[illegible]	85-8-46	8/26/85		6.9		1310	1030	154	61	47	3	505	19	257		314		<0.05	<0.1	<0.005	<0.001		<0.01
[illegible]	86-5-27	5/15/86																					
[illegible]	86-7-13	7/10/86		7.5		1400	1000	140	50	45	3	446	17	256		315		<0.05					
[illegible]	86-12-13	12/5/86		7.3		1380	1040	155	64	48	3	529	22	253		309		<0.05	<0.1	<0.005	<0.001	<0.02	<0.01
[illegible]	87-3-1	3/2/87																					
[illegible]	87-3-14	3/30/87		7.2		1220	1030							249				<0.05					
[illegible]	87-3-14	3/26/87																					
[illegible]	87-5-6	5/7/87		5.3		17	12							5									
[illegible]	87-5-24	5/19/87		7.2		1380	1010	158	69	47	2	563	19	257		314							
[illegible]	87-7-3	7/8/87																					
[illegible]	87-8-11	8/10/87																					
[illegible]	87-11-12	11/16/87		7.2		1425	1130							234				<0.05					
[illegible]	88-3-25	3/29/88		8.2		1450	1150							252				<0.05					
[illegible]	88-10-8	10/20/88																					
[illegible]	89-1-4	1/4/89																					
[illegible]	89-2-1	2/7/89		7.5		1490	1160							253									
[illegible]	89-5-3	5/12/89																					
[illegible]	89-10-9	10/23/89																					
[illegible]	90-3-8	3/16/90		7.6		1490	1160							251				<0.05					
[illegible]	91-1-25	1/8/91																					
[illegible]	91-7-41	7/31/91																					
[illegible]	92-10-60	10/27/92		7.6		1530	1060							255				0.21					
[illegible]	92-12-4	12/9/92		7.8		1360	1040	160	66	48	4	550	27	252		308		0.19					
[illegible]	93-1-26	1/6/93																					
[illegible]	93-2-30	2/8/93																<0.05					
[illegible]	93-3-24	3/18/93																<0.05					
[illegible]	93-4-15	4/8/93																<0.05					
[illegible]	93-5-37	5/19/93																<0.05					
[illegible]	93-6-8	6/8/93																<0.05					
[illegible]	93-7-24	7/20/93																<0.05					
[illegible]	93-9-26	9/15/93																0.32					
[illegible]	93-10-11	10/11/93																					
[illegible]	93-11-6	11/10/93																0.26					
[illegible]	94-1-10	1/5/94																0.18					
[illegible]	94-7-28	7/14/94																0.38					
[illegible]	94-8-38	8/18/94		7.5		1630	1240							247				0.09					
[illegible]	95-1-5	1/10/95	7.03	7.7	1391	1530	1240											0.28					
[illegible]	95-7-45	7/18/95	7.01	7.1	1530	1540	1300											0.09					
[illegible]	96-3-108	3/25/96	6.65	7.3	1540	1600	1230										0.14	0.53					

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SITE	SAMPLE NO	DATE	pH-Field	pH-Lab	SC-Field	SC-Lab	TDS	Calcium	Magnesium	Sodium	Potassium	Sulfate	Chloride	Alkalinity	Acidity	Bicarbonate	Ammonia	Nitrate+Nitrite	Aluminum	Arsenic	Cadmium	Chromium	Copper
[illegible]	[illegible]	[illegible]	[illegible]	7	[illegible]	[illegible]	[illegible]										0.12	0.12					
[illegible]	[illegible]	[illegible]	[illegible]	7.3	[illegible]	[illegible]	[illegible]										<0.05	1.29					
[illegible]		Mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	47	3	[illegible]	[illegible]	[illegible]	ND	312	[illegible]	[illegible]	0.1	0.005	0.001	0.02	0.01
		Median	[illegible]	7.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	47	3	[illegible]	19	252	ND	314	0.12	[illegible]	0.1	0.005	0.001	0.02	0.01
		GeoMean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	ND	[illegible]	[illegible]	[illegible]	0.1	0.005	0.001	0.02	0.01
		Min	[illegible]	[illegible]	[illegible]	17	12	[illegible]	[illegible]	[illegible]	2	[illegible]	17	[illegible]	ND	[illegible]	[illegible]	[illegible]	0.1	0.005	0.001	0.02	0.01
		Max	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4	[illegible]	27	[illegible]	ND	[illegible]	0.14	1.29	0.1	0.005	0.001	0.02	0.01
SITE	SAMPLE NO	DATE	pH-Field	pH-Lab	SC-Field	SC-Lab	TDS	Calcium	Magnesium	Sodium	Potassium	Sulfate	Chloride	Alkalinity	Acidity	Bicarbonate	Ammonia	Nitrate+Nitrite	Aluminum	Arsenic	Cadmium	Chromium	Copper
[illegible]	[illegible]	[illegible]	7.32		330																		
[illegible]	[illegible]	[illegible]																0.14					
[illegible]	[illegible]	[illegible]																<0.05					
[illegible]	[illegible]	[illegible]																					
[illegible]	[illegible]	[illegible]																					
[illegible]	[illegible]	[illegible]																					
[illegible]	[illegible]	[illegible]																					
[illegible]	[illegible]	[illegible]																					
[illegible]	[illegible]	[illegible]		7.6		[illegible]	294	13	1	[illegible]	3	54	9	176		215	<0.1	<0.05					
[illegible]	[illegible]	[illegible]																					
[illegible]	[illegible]	[illegible]																					
[illegible]	[illegible]	[illegible]																<0.05					
[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]							[illegible]				0.1					
[illegible]	[illegible]	[illegible]		8.1		[illegible]	[illegible]							176				0.13					
[illegible]	[illegible]	[illegible]																0.07					
[illegible]	[illegible]	[illegible]																0.11					
[illegible]	[illegible]	[illegible]																0.15					
[illegible]	[illegible]	[illegible]																<0.05					
[illegible]	[illegible]	[illegible]																<0.05					
[illegible]	[illegible]	[illegible]																<0.05					
[illegible]	[illegible]	[illegible]		8.4		[illegible]	[illegible]											<0.05					
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]											<0.05					
[illegible]	[illegible]	[illegible]	[illegible]	8	[illegible]	[illegible]	[illegible]										<0.05	<0.05					
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]										<0.05	<0.05					
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]										[illegible]	<0.05					
[illegible]		Mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13	1	[illegible]	3	54	9	252	ND	215	[illegible]	[illegible]	ND	ND	ND	ND	ND
		Median	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13	1	[illegible]	3	54	9	176	ND	215	[illegible]	[illegible]	ND	ND	ND	ND	ND
		GeoMean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13	1	[illegible]	3	54	9	[illegible]	ND	215	[illegible]	[illegible]	ND	ND	ND	ND	ND
		Min	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13	1	[illegible]	3	54	9	176	ND	215	[illegible]	[illegible]	ND	ND	ND	ND	ND
		Max	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	13	1	[illegible]	3	54	9	[illegible]	ND	215	0.1	[illegible]	ND	ND	ND	ND	ND
Overall		Mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.1	[illegible]	0.001	0.02	[illegible]
		Median	[illegible]	7.8	2110	[illegible]	[illegible]	[illegible]	[illegible]	130	16.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.1	[illegible]	0.001	0.02	0.01
		GeoMean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.1	[illegible]	0.001	0.02	[illegible]
		Min	[illegible]	[illegible]	[illegible]	17	12	7	1	25	2	40	0	0	0	[illegible]	[illegible]	[illegible]	0.1	[illegible]	0.001	0.02	0.01
		Max	[illegible]	12	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1230	20	[illegible]	[illegible]	[illegible]	0	[illegible]	0.14	[illegible]	0.1	[illegible]	0.001	0.02	0.11

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SITE	SAMPLE NO	DATE	Iron-Diss	Lead-Diss	Manganese	Mercury-D	Molybden	Nickel-Dis	Selenium	Antimony	Barium-D	Beryllium	Thallium	Silver-Dis	Zinc-Diss	CN-Amen	TotalCN	WADCN	Hardness	Flouride	Nitrate	Nitrite	Phosphat
L FEIGHT	86-4-21	4/20/86															<0.005						
L FEIGHT	86-2-24	2/25/86	0.06														<0.005						
L FEIGHT	87-4-13	4/15/87															<0.007						
L FEIGHT	87-10-13	10/14/87															<0.005						
L FEIGHT	88-1-22	1/27/88															<0.005						
L FEIGHT	88-4-17	4/27/88															<0.005						
L FEIGHT	88-11-7	11/4/88															<0.005						
L FEIGHT	89-3-10	3/24/89															<0.005						
L FEIGHT	89-7-3	7/5/89															<0.005						
L FEIGHT	89-11-3	11/13/89															<0.005						
L FEIGHT	90-3-2	3/6/90															<0.005						
L FEIGHT	90-8-2	8/2/90															<0.005						
L FEIGHT	90-12-19	12/20/90															<0.005						
L FEIGHT	92-1-19	1/20/92															<0.005						
L FEIGHT	92-4-38	4/15/92															<0.005						
L FEIGHT	92-7-35	7/27/92															<0.005						
L FEIGHT	92-10-18	10/13/92															<0.005						
L FEIGHT	93-1-23	1/6/93															<0.005						
L FEIGHT	93-4-14	4/6/93															<0.005						
L FEIGHT	93-7-25	7/16/93															<0.005						
L FEIGHT	93-10-10	10/11/93															<0.005						
L FEIGHT	94-1-9	1/5/94															<0.005						
L FEIGHT	94-7-1	7/1/94	0.23														<0.005						
L FEIGHT	95-7-46	7/19/95															<0.005						
L FEIGHT	95-7-65	7/24/95															<0.005						
L FEIGHT		Mean	0.145	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.005	ND	ND	ND	ND	ND	ND
		Median	0.145	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.005	ND	ND	ND	ND	ND	ND
		CoeffDev	0.11747	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.005	ND	ND	ND	ND	ND	ND
		Min	0.06	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.005	ND	ND	ND	ND	ND	ND
		Max	0.23	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.005	ND	ND	ND	ND	ND	ND
SITE	SAMPLE NO	DATE	Iron-Diss	Lead-Diss	Manganese	Mercury-D	Molybden	Nickel-Dis	Selenium	Antimony	Barium-D	Beryllium	Thallium	Silver-Dis	Zinc-Diss	CN-Amen	TotalCN	WADCN	Hardness	Flouride	Nitrate	Nitrite	Phosphat
DECORAH	85-12-14	12/20/85																					
DECORAH	86-1-5	01/08/86															<0.01						
DECORAH	86-2-1	02/11/86															0.008						
DECORAH	86-2-15	02/25/86															<0.005						
DECORAH	86-3-4	03/13/86															<0.004						
DECORAH	86-3-8	03/17/86															0.005						
DECORAH	86-3-14	03/21/86															<0.005						
DECORAH	86-3-20	03/25/86															0.011						
DECORAH	86-3-33	03/28/86															0.006						
DECORAH	86-4-12	04/11/86															<0.005						
DECORAH	86-4-25	04/30/86															<0.005						
DECORAH	86-5-20	05/15/86															0.018						
DECORAH	86-6-27	06/13/86															<0.005						
DECORAH	86-7-2	07/01/86															<0.005						
DECORAH	86-7-32	07/29/86	0.44	<0.01	0.03	<0.001	<0.005	<0.03	0.007					<0.005	0.05		0.019						
DECORAH	87-2-7	02/12/87															0.086						
DECORAH	87-6-13	06/18/87														0.106	0.106	0.041					
DECORAH	87-6-22	06/20/87															<0.005						
DECORAH	88-1-10	01/15/88															0.055						
DECORAH	88-1-11	01/16/88															0.074						
DECORAH	88-3-26	03/24/88															0.128						
DECORAH	89-2-22	02/21/89															0.208						
DECORAH	89-6-27	06/21/89															0.26						
DECORAH	89-7-16	07/17/89															0.094	0.028					
DECORAH	89-7-6	07/25/89															0.063						
DECORAH	89-11-4	11/15/89															0.062						
DECORAH	90-3-10	03/16/90															0.091						
DECORAH	90-6-4	06/02/90															0.061						
DECORAH	90-12-6	12/17/90															0.125						
DECORAH	91-6-2	06/04/91															0.005						
DECORAH	91-10-22	10/25/91															0.018	0.011					
DECORAH	91-10-14	10/22/91															0.01	<0.005					
DECORAH	92-4-52	04/24/92															0.016	0.008					
DECORAH	92-7-42	07/27/92															0.031	0.016					
DECORAH	92-10-14	10/13/92															0.043	0.04					
DECORAH	93-1-27	01/12/93															0.067	<0.005					
DECORAH	93-4-26	04/16/93															0.02	0.009					
DECORAH	93-7-32	07/27/93															<0.005						
DECORAH	93-10-17	10/12/93															0.042						

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SITE	SAMPLEID(NO)	DATE	Iron-Diss	Lead-Diss	Manganes	Mercury-D	Molybden	Nickel-Dis	Selenium	Antimony	Barium-D	Beryllium	Thallium	Silver-Dis	Zinc-Diss	CN-Amen	TotalCN	WADCN	Hardness	Flouride	NitrateasN	NitriteasN	Phosphat
SH-2KH	96-7-46	7/24/96															<0.005						
SH-2KH	97-3-83	3/25/97															<0.005						
SH-2KH		Mean	0.37667	0.01	0.176	0.001	0.006	0.03	0.006	ND	ND	ND	ND	0.006	0.87	0.006	0.01663	0.006	ND	ND	ND	ND	ND
		Median	0.32	0.01	0.176	0.001	0.006	0.03	0.006	ND	ND	ND	ND	0.006	0.87	0.006	0.006	0.006	ND	ND	ND	ND	ND
		GeoMean	0.29537	0.01	0.17493	0.001	0.006	0.03	0.006	ND	ND	ND	ND	0.006	0.52991	0.006	0.00631	0.006	ND	ND	ND	ND	ND
		Min	0.08	0.01	0.17	0.001	0.006	0.03	0.006	ND	ND	ND	ND	0.006	0.16	0.006	0.004	0.006	ND	ND	ND	ND	ND
		Max	0.73	0.01	0.18	0.001	0.006	0.03	0.006	ND	ND	ND	ND	0.006	1.58	0.006	0.38	0.006	ND	ND	ND	ND	ND
SITE	SAMPLEID(NO)	DATE	Iron-Diss	Lead-Diss	Manganes	Mercury-D	Molybden	Nickel-Dis	Selenium	Antimony	Barium-D	Beryllium	Thallium	Silver-Dis	Zinc-Diss	CN-Amen	TotalCN	WADCN	Hardness	Flouride	NitrateasN	NitriteasN	Phosphat
HMLA	88-2-7	2/11/88															<0.005						
HMLA	88-3-12	3/23/88															0.01						
HMLA	88-4-23	4/30/88															<0.005						
HMLA	89-1-21	1/27/89															<0.005						
HMLA	89-7-1	7/5/89															<0.005						
HMLA	90-3-7	3/6/90															<0.005						
HMLA	90-6-1	6/7/90															<0.005						
HMLA	90-6-3	6/7/90															<0.005						
HMLA	90-12-18	12/26/90															<0.005						
HMLA	92-1-18	1/29/92															<0.005						
HMLA	92-4-40	4/15/92															<0.005						
HMLA	92-7-38	7/27/92															<0.005						
HMLA	92-10-10	10/13/92															<0.005						
HMLA	93-1-22	1/6/93															<0.005						
HMLA	93-4-13	4/8/93															<0.005						
HMLA	93-7-16	7/16/93															<0.005						
HMLA	93-10-9	10/15/93															<0.005						
HMLA	94-1-8	1/5/94															<0.005						
HMLA	94-7-24	7/14/94															<0.005						
HMLA	95-1-11	1/10/95															<0.005						
HMLA	95-7-47	7/18/95															<0.005						
HMLA	96-3-109	3/25/96															<0.005						
HMLA	96-7-47	7/24/96															<0.005						
HMLA	97-3-82	3/25/97															<0.005						
HMLA		Mean	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.00521	ND	ND	ND	ND	ND	ND
		Median	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.005	ND	ND	ND	ND	ND	ND
		GeoMean	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.00515	ND	ND	ND	ND	ND	ND
		Min	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.005	ND	ND	ND	ND	ND	ND
		Max	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.01	ND	ND	ND	ND	ND	ND
Overall		Mean	0.14156	0.01	0.075	0.001	0.006	0.01619	0.0065	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	0.006	0.165	0.03654	0.02584	0.013	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
		Median	0.056	0.01	0.03	0.001	0.006	0.01	0.007	#NUM!	#NUM!	#NUM!	#NUM!	0.006	0.045	0.01625	0.005	0.006	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!
		GeoMean	0.07501	0.01	0.04717	0.001	0.006	0.01405	0.00625	#NUM!	#NUM!	#NUM!	#NUM!	0.006	0.05662	0.01619	0.01050	0.0066	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!
		Min	0.083	0.01	0.02	0.001	0.006	0.01	0.006	0	0	0	0	0.006	0.01	0.006	0.004	0.006	0	0	0	0	0
		Max	0.73	0.01	0.18	0.001	0.006	0.03	0.01	0	0	0	0	0.006	1.58	0.131	0.38	0.006	0	0	0	0	0

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I) Residential Wells Southwest of Project Site

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Golden Sunlight Mines, Inc.
Residential Wells -- Southwest of Project Site
Ambient Groundwater Quality

Parameter (mg/L)	C Davis	J Davis	G Burell	Mean	Median	GeoMean	Min	Max
sulfate	1870	752	412	1011	752	834	412	1870
arsenic	<0.005	<0.005	0.005	0.005	0.005	0.005	0.005	0.005
cadmium	<0.001	<0.001	<0.001	0.001	0.001	0.001	0.001	0.001
copper	<0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
chromium	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.01	0.01
iron	14.3	3.13	<.03	8.715	8.715	6.69	3.13	14.3
lead	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.01	0.01
manganese	0.36	0.05	<0.01	0.14	0.05	0.056	0.01	0.36
nickel	nd	nd	nd	nd	nd	nd	nd	nd
selenium	<0.005	<0.005	<0.005	0.005	0.005	0.005	0.005	0.005
zinc	<0.01	<0.01	0.16	0.06	0.01	0.025	0.01	0.16
NO_2+NO_3	<0.05	<0.05	1.53	0.543	0.05	0.156	0.05	1.53

Samples collected 1/24/97.

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J) Treatment Plant Discharge Percolation Pond Area

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Golden Sunlight Mines, Inc.
Treatment Plant Discharge Percolation Pond Area
Ambient Groundwater Quality

Parameter	Mean (mg/L)	Geometric Mean (mg/L)	Minimum (mg/L)	Maximum (mg/L)
pH	7.2	7.1	6.3	7.8
TDS	1935	1549	530	3100
sulfate	868	648	190	1510
NO_2+NO_3	41	23.6	2.46	80
aluminum	0.1	0.1	0.1	0.1
antimony	nd	nd	nd	nd
arsen	0.005	0.005	0.005	0.005
barium	0.1	0.1	0.1	0.1
beryllium	nd	nd	nd	nd
cadmium	0.001	0.001	0.001	0.001
copper	0.02	0.018	0.01	0.03
chromium	nd	nd	nd	nd
iron	0.03	0.03	0.03	0.03
lead	0.01	0.01	0.01	0.01
manganese	0.013	0.012	0.01	0.02
mercury	nd	nd	nd	nd
nickel	nd	nd	nd	nd
selenium	nd	nd	nd	nd
silver	0.005	0.005	0.005	0.005
thallium	nd	nd	nd	nd
zinc	0.07	0.069	0.08	0.06

NOTES:

All concentrations in mg/L.

Concentrations calculated from most recent data for four wells:

Well	Sample Date
OW-2	(3/12/97)
OW-3	(3/12/97)
OW-5	(9/17/86)
OW-7	(12/28/89)

nd = no data for this parameter.

Below detect values replaced by the detection limit for calculations.

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SITE	SAMPLE	DATE	Iron Dis	Lead Diss	Manganese	Mercury D	Molybden	Nickel Dis	Selenium	Silver Dis	Zinc Diss	CN Amen	Total CN	WAD CN	Hardness	Fluoride D	Nitrate as	Nitrite as	Phosphor	Antimony	Barium D	Beryllium	Thallium
			FE-D	PB-D	MN-D	HG-D	MO-D	NI-D	SE-D	AG-D	ZN-D	CN-AMN	CN-T	CN-WAD	HARD	F-D	NO3	NO2	P-ORTH	SB-D	BA-D	BE-D	TL-D
DW-2	97-3-48	3/12/97	<0.03		<0.01						0.07					0.79			0.04		<0.1		
DW-3	97-3-50	3/12/97	<0.03		<0.01						0.06					0.71			0.02		<0.1		
DW-5	98-8-11	8/17/98											<0.005										
DW-7	98-12-18	12/26/98	<0.03	<0.01	<0.02		<0.005			<0.005	0.08		0.105										
		Mean	0.03	0.01	0.013333	#DIV/0!	0.005	#DIV/0!	#DIV/0!	0.005	0.07	#DIV/0!	0.055	#DIV/0!	#DIV/0!	0.75	#DIV/0!	#DIV/0!	0.03	#DIV/0!	0.1	#DIV/0!	#DIV/0!
		Median	0.03	0.01	0.01	#NUM!	0.005	#NUM!	#NUM!	0.005	0.07	#NUM!	0.055	#NUM!	#NUM!	0.75	#NUM!	#NUM!	0.03	#NUM!	0.1	#NUM!	#NUM!
		GeoMean	0.03	0.01	0.0126	#NUM!	0.005	#NUM!	#NUM!	0.005	0.06952	#NUM!	0.02291	#NUM!	#NUM!	0.74893	#NUM!	#NUM!	0.02828	#NUM!	0.1	#NUM!	#NUM!
		Max	0.03	0.01	0.02	0	0.005	0	0	0.005	0.08	0	0.105	0	0	0.79	0	0	0.04	0	0.1	0	0
		Min	0.03	0.01	0.01	0	0.005	0	0	0.005	0.06	0	0.005	0	0	0.71	0	0	0.02	0	0.1	0	0

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K) West Waste Rock Dump -- East Flank

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SITE	SAMPLE	DATE	pH-Field PH-F	pH-Lab PH-L	SC-Field COND-F	SC-Lab COND-L	TDS TDS	Calcium CA-D	Magnesium MG-D	Sodium NA-D	Potassium K-D	Sulfate SO4-T	Chloride CL-T	Alkalinity ALK-T	Acidity ACID-T	Bicarbonate HCO3	Ammonia NH3	Nitrate-N NO3NO2	Aluminum AL-D	Arsenic AS-D	Cadmium CD-D	Chromium CR-D	Copper CU-D
[illegible]		Mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Median	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		GeoMean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Max	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Min	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		Mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Median	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		GeoMean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Max	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Min	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		Mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Median	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		GeoMean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Max	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Min	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]		Mean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Median	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		GeoMean	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Max	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
		Min	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

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L1 West Waste Rock Dump – West Flank

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M) Steppan Spring Original Location

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N) Impoundment No. 1 Main Drain

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APPENDIX C

REVISED SLUDGE DISPOSAL PLAN

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GOLDEN SUNLIGHT MINES, INC.

MEMORANDUM

Date: November 6, 1996

To: **Ray Lazuk**

cc: Jerry Harrington
Rick Dale

From: Al Storey

Re: **Water Treatment Plant Sludge Disposal**

Please review and comment on the attached description of sludge disposal for our proposed water treatment plant. This will be submitted to the engineering contractor responsible for the EIS.

I've also included my assumptions and calculations.

Thank you.

Al Storey

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Golden Sunlight Mines, Inc.
Water Treatment Plant
Sludge Disposal

Introduction

Waste sludge from the water treatment plant will be dewatered using a filter press rather than relying on solar evaporation. This will reduce concerns associated with dust and pond leaks. Also, use of a filter press will provide a more manageable means of sludge disposal. Sludge will either be pumped with a high-solids slurry pump or trucked to a landfill disposal area located on the surface of Tailing Impoundment No. 2. Landfill cells will be provided with geomembrane liners. The tailing impoundment liner will provide a secondary leakage containment system.

Sludge Volume

Sludge volumes were estimated by Hydrometrics, Inc. (Robert Kimball and Mark Reinsel, August, 1996). A sludge volume of 17 cubic yards per day is expected from plant startup through year 10 and a sludge volume of 21 cubic yards per day is expected beyond year 10. The dewatered sludge will have a minimum solids content of 50% by weight.

Sludge Disposal

At the landfill, sludge will be disposed of in thin lifts that will periodically be disked and will be allowed to dry to 20% moisture content. These lifts will then be compacted to at least 90% relative density using a vibratory sheepsfoot compactor. Compacted sludge volumes will be 8.64 cubic yards per day in years 0 through 10 and 10.66 cubic yards per day beyond year 10.

A typical cross section of a sludge disposal cell on the surface of Tailing Impoundment No. 2 is shown in Figure 1. Cells will be bounded by 24 foot high compacted fill berms. Drain pipes will allow rain water to be drained to a reclaim pond. This water will then either gravity flow or be pumped back to the water treatment plant. Active cells will be surrounded by wildlife control fences and reclaim ponds will be provided with bird netting. At least two cells will be active at any time to allow sludge disposal in one cell while the upper lift in the second cell is being disked, drying out or being compacted.

Storage Requirement

In years 0 through 10, two 184 foot square cells will be required. Beyond year 10, cells will be 200 feet square. Each cell will be filled until the sludge eventually reaches a depth of 20 feet. This corresponds to a storage capacity of 5 years worth of sludge production per cell. The final surface area of Tailing Impoundment No. 2 will be 185.5 acres. This will provide adequate storage area for over 1,000 years worth of sludge production.

Cell Closure

Prior to construction of a landfill cell, impoundment No. 2 reclamation capping materials will be stripped and stockpiled. At cell closure, a geomembrane liner will be placed over the surface of the compacted sludge. The stockpiled capping materials will then be placed over the geomembrane and vegetation will be reestablished.

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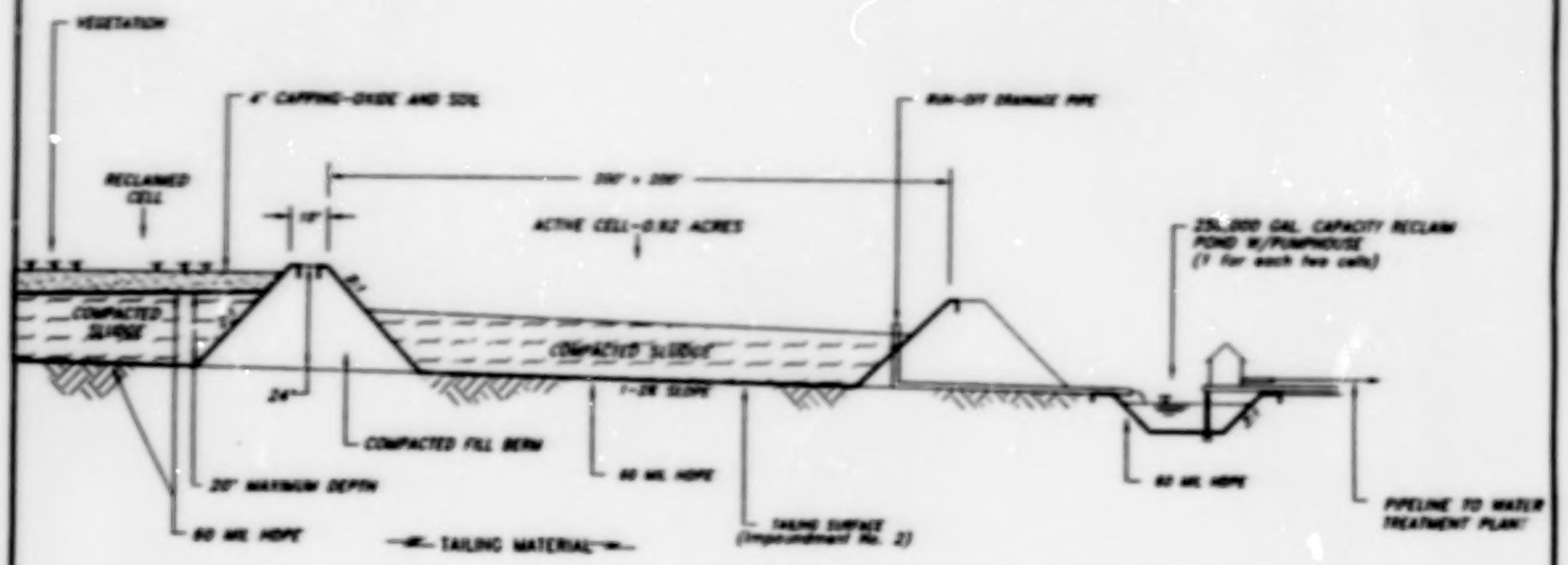

GOLDEN SUNLIGHT MINE

FIGURE C-1

Sludge Disposal Cell on the Surface of Tailings Impoundment No. 2

DATE NOV. 6,1990	SCALE	DRAWN BY A. STOREY
REVISION	NONE	DRAFTED BY V. RODRIGUEZ
REVISION		DWG. No.

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M3 ENGINEERING & TECHNOLOGY

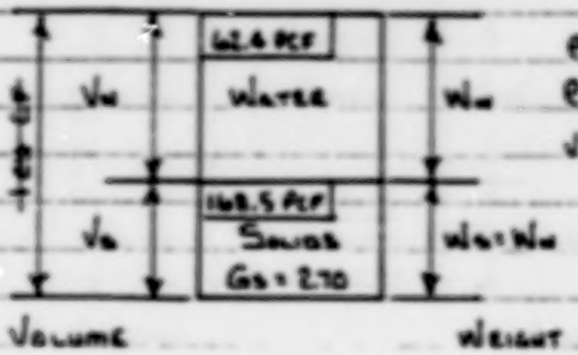
PROJECT No. ______
PROJECT EIS
SHEET No. 1 **OF** 4 **BY** A.S.
DRAWING No. ______

SUBJECT: SLUDGE DISPOSAL **DATE:** NOV. 5, '96

PER HYDROMETRICS, INC., "DESIGN AND ESTIMATED COSTS FOR PIT AND TAILINGS WATER TREATMENT PLANT AT GSM", AUG. '96:

SLUDGE VOL.	YRS. 0-10	17 CY/DAY	@ 50% SOLIDS BY WEIGHT
	YRS. > 10	21 CY/DAY	(DEWATERED SLUDGE)

DEWATERED SLUDGE WILL BE SATURATED



$\rho_W = 62.4$ LBS/FT^3
$\rho_S = 2.7(62.4) = 168.5$ LBS/FT^3
$V = W/\rho$

IF WEIGHT OF BLOCK IS 1 LB., THEN

$$V_S = \frac{.5 \text{ LBS}}{168.5 \text{ LB/CF}} = 0.0030 \text{ CF}$$

$$V_W = \frac{.5 \text{ LBS}}{62.4 \text{ LB/CF}} = 0.0080 \text{ CF}$$

0.0110 CF

VOL. OF SOLIDS IN 1 CY OF DEWATERED SLUDGE:

$$\% \text{ SOLIDS BY VOL.} = \frac{.0030}{.0110} \times 100 = 27.27\%$$

SLUDGE SOLIDS PRODUCED:	YRS. 0-10	4.64 CY/DAY
	YRS. > 10	5.73 CY/DAY

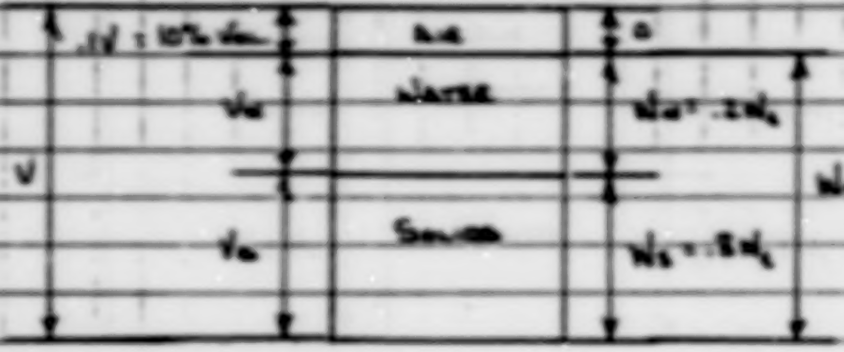
ASSUME SLUDGE WILL BE COMPACTED TO 10% AIR VOIDS AT 20% MOISTURE CONTENT BY WEIGHT.

SLUDGE WILL BE DRIED FROM 50% M.C., THEN DISCED TO DISTRIBUTE MOISTURE. THE COMPACTION PROCESS WILL THEN BE APPLIED.

M3 ENGINEERING & TECHNOLOGY

PROJECT No. ______
PROJECT KCS
SHEET No. 2 OF 4 BY K.S.
DRAWING No. ______

SUBJECT: Sludge Disposal DATE: Jan. 5, '96



Equations: $V = .1V + V_w + V_s$
$V_w = W_w/\rho_w = .2\,W_t/\rho_w$
$V_s = W_s/\rho_s = .8\,W_t/\rho_s$

Assume Total Weight, $W_t = 1$ LB. → $V_w = \dfrac{.2 \text{ LBS.}}{62.4 \text{ LBS/CF}} = .0032$ CF
$V_s = \dfrac{.8 \text{ LBS.}}{168.5 \text{ LBS/CF}} = .0047$ CF

$V = .1V + V_w + V_s$
$.9V = V_w + V_s = .0032 + .0047 = .0079$ CF → $V = \dfrac{.0079}{.9} = .0088$ CF

∴ 1 LB. of Compacted Sludge will occupy a vol. of 0.0088 CF

Compacted Density = 1/.0088 = 113.24 LBS./CF (This will be 90 to 95% Relative Compaction)

Weight of Sludge Produced Per Day:

YRS. 0-10 : (4.64 CY Solids / Day)(168.5 LBS./FT^3)(27 CF/CY) = 21,110 LBS./Day
YRS. >10 : (5.73 CY Solids/Day) ↓ ↓ = 26,069 LBS./Day
Solids Only

$W_s = .8\,W_t$
$W_w = .2\,W_t \rightarrow W_t = W_w/.2$
$W_s = .8(W_w/.2) = 4W_w \rightarrow W_w = .25\,W_s$

$W_t = W_w + W_s = .25\,W_s + W_s = 1.25\,W_s = 1.25$(Solids)

PROJECT No. ____________

M3 ENGINEERING & TECHNOLOGY

PROJECT EIS
SHEET No. 3 **OF** 4 **BY** A.S.
DRAWING No. ____________

SUBJECT: Sludge Disposal **DATE:** Nov 5. '96

Yrs. 0-10: $W_w = 1.25(21{,}110) = 26{,}388$ LBS.
Yrs. >10: $W_w = 1.25(26{,}069) = 32{,}586$ LBS.

Volume of Compacted Sludge Produced Per Day:

Yrs. 0-10: $V_w = W_w/\rho_w = .25\,W_s/\rho_w = .25(21{,}110)/62.4$
$= 84.58$ CF / Day
$V_s = W_s/\rho_s = 21{,}110/168.5 = 125.28$ CF / Day
$V_v = 0.1\,V$ (Voids)

$V = .1V + 84.58 + 125.28 \rightarrow V = 233.2$ CF / Day
$= \boxed{8.64 \text{ CY / Day}}$

Yrs. >10: $V_w = .25\,W_s/\rho_w = .25(26{,}069)/62.4 = 104.44$ CF / Day
$V_s = W_s/\rho_s = 26{,}069/168.5 = 154.71$ CF / Day

$V = .1V + 104.44 + 154.71 \rightarrow V = 288.0$ CF / Day
$= \boxed{10.66 \text{ CY / Day}}$

Landfill Design:

Assume landfill cells will be constructed on the surface of Tailings Impoundment No. 2 and that cells will accommodate 5 yrs. worth of sludge disposal. Also, sludge will be stored to maximum depths of 20 ft.

Cell Size:

Yrs. 0-10: 2 cells Req'd. Vol. to be disposed in each cell:
$V = 15{,}768$ CY $= 425{,}736$ CF

Cell Size = 21,286 SF (@ Depth = 20 ft.)
Sq. Size = 146 ft. x 146 ft.

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SUBJECT: SLUDGE DISPOSAL **DATE:** JAN. 5, '96

YRS. 7-10: VOL. TO BE DISPOSED IN EA. CELL TO ACCOMMODATE 6 YRS.
STORAGE CAPACITY = 19,455 CY = 525,272 CF

CELL SIZE = 26,264 SF (@ DEPTH = 20FT.)
SQ. SIZE = 162 FT. x 162 FT.

STORAGE CAPACITY OF NO. 2 IMPOUNDMENT SURFACE:

TOTAL SURFACE AREA = 185.5 ACRES

FOR AN AV. 150' SQ. CELL SIZE, BERMS WILL TAKE UP APPROX. 34.0% OF THE SURFACE AREA.

AVAIL. STORAGE AREA = 122.4 ACRES

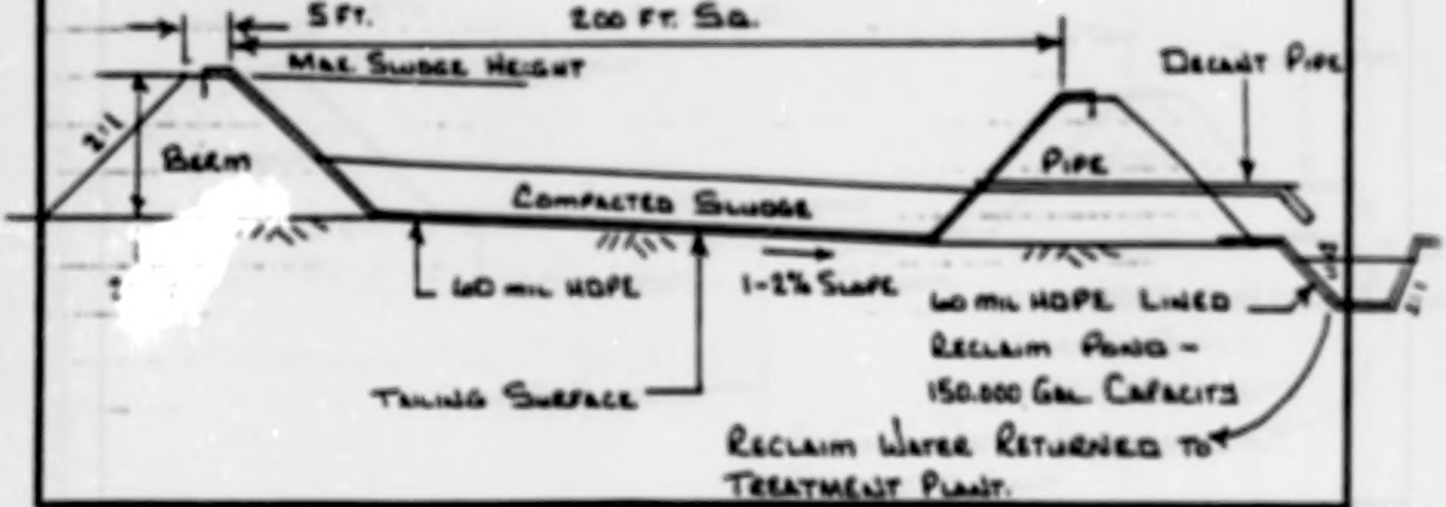
AREA USED UP IN YRS. 0-10 = 0.98 AC.

REMAINING AREA AVAIL. = 122.40 - .98 = 121.42 AC.

BEYOND YR. 10, 0.1208 AC. WILL BE REQ'D EA. YR.

NO. YRS. STORAGE CAPACITY AVAIL. = $10 + \frac{121.42}{.1208} = \boxed{1,016 \text{ YRS.}}$

CELL DESIGN: TYPICAL



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APPENDIX D

ECONOMIC ANALYSIS FOR COMPLETE PIT BACKFILLING

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Calculation of Economic Feasibility of Complete Backfilling

A rough calculation of the economic feasibility of complete backfilling of the pit was conducted using the formulas and variables described below.

BASIC FORMULAS

Two basic formulas are used in the analysis:

1) **Gross Value of Ore** - **Operating Cost** = **Profit**

2) **Profit** - **Backfilling Cost** = **Profit after Backfilling**

(All values are expressed in units per ton of material mined.)

The level of profit remaining after backfilling determines the economic feasibility of backfilling the pit.

VARIABLES

Variables used in the analysis include the following:

Variable	Value	Source
Average Ore Grade	0.06 opt (ounces of gold per ton of ore)	Typical grade for a mine with ore similar to Golden Sunlight's
Average Gold Price	$370 per oz.	Current average market rate
Average Recovery Efficiency	75%	Typical for a mine similar to Golden Sunlight
Stripping Ratio	8.22:1 (waste rock to ore)	Golden Sunlight typical stripping ratio
Average Operating Cost	$320 per oz.	Standard weighted average cost in the industry.
Average Backfill Cost	$81,376,000	Average of estimates generated from the FPC computer program and from information in the Caterpillar handbook. (See Attachment 1)
Total Tons Mined Used to Backfill	249,000,000 tons	Golden Sunlight calculation

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BASE CASE

A base case scenario is used to generate a typical profit estimate and profit after backfilling estimate. A range can then be generated for optimistic and pessimistic scenarios based on varying values of the input variables for gross value of ore, operating cost, and backfilling cost.

Gross Value of Ore:

$$\frac{0.06\text{ oz.}}{\text{ton ore}} \times \frac{1\text{ ton ore}}{9.22\text{ tons total}} \times \frac{\$370}{\text{oz.}} \times 0.75 = \$1.81\text{ per total tons of material}$$

Operating Costs:

$$\frac{\$320}{\text{oz.}} \times \frac{0.06\text{ oz.}}{\text{ton ore}} \times \frac{1\text{ ton ore}}{9.22\text{ tons total}} \times 0.75 = \$1.56\text{ per total tons of material}$$

Backfilling Costs:

$$\$81{,}378{,}000 \times \frac{1}{249{,}000{,}000\text{ tons}} = \$0.33\text{ per ton of material}$$

Profit:

$$\underline{\$1.81} - \underline{\$1.56} = \underline{\$0.25}$$

Profit After Backfilling:

$$\underline{\$0.25} - \underline{\$0.33} = \underline{-\$0.08}$$

HIGH AND LOW RANGE PROFIT ESTIMATES

Under the low range scenario, variables include a gold price of $350 per oz. and a recovery efficiency of 70 percent. The gross value of ore is then $1.59 per ton, and the operating cost is $1.46 per ton. The estimated profit is $0.14 per ton. The estimated profit after backfilling is -$0.19 per ton.

Under the high range scenario, variables include a gold price of $400 per oz. and a recovery efficiency of 80 percent. The gross value of ore is then $2.08 per ton, and the operating cost is $1.67 per ton. The estimated profit is $0.42 per ton. The estimated profit after backfilling is $0.09 per ton.

COMPARISON OF SCENARIOS

Scenario	Gross Value of Ore	Operating Cost	Profit	Profit After Backfilling
Base Case	$1.81 per ton	$1.56 per ton	$0.25 per ton	-$0.08 per ton
Low Range	$1.59 per ton	$1.46 per ton	$0.14 per ton	-$0.19 per ton
High Range	$2.08 per ton	$1.67 per ton	$0.42 per ton	$0.09 per ton

VARIATIONS IN PIT BACKFILLING COSTS

Backfilling the pit with waste rock is only economically viable if it does not involve double handling of waste rock in amounts representing a substantial percentage of the total tonnage, or if the hauling distances are substantially reduced. However, the hauling distances at Golden Sunlight are dictated by the current mine layout, and cannot be altered to the degree necessary to render the Complete Backfill Alternative viable.

CONCLUSION

The profit remaining after backfilling for a typical scenario is -$0.08 per ton. A range of possible variable values yields an estimated range of profit after backfilling of -$0.19 per ton to $0.09 per ton. None of the scenarios generated a profit after backfilling that would make backfilling the pit economically feasible. Even under the high range scenario, a profit margin of $0.09 per ton is too low to make backfilling the pit feasible because other costs, such as capital costs and permitting costs, have not been included. Backfilling costs cannot be altered to the degree necessary to make the Complete Backfill Alternative viable.

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Attachment #1
Calculation of Total Backfilling Costs

APPROACH #1-Computerized Estimation of Backfilling Costs

a) average haul route profiles

East Dump Complex			West Dump Complex		
Distance (slope, feet)	Grade Resistance (%)	Rolling Resistance (%)	Distance (slope, feet)	Grade Resistance (%)	Rolling Resistance (%)
200	0	3	200	0	3
1180	0	2	2500	4	2
400	-10	2	200	0	3
1580	-7	2			
3000	1.7	2			
200	0	3			

b) efficiencies

mechanical availability = 82%
utilization of time = 83%

c) complete backfill tonnage

West Dump Complex = 194,000,000 tons
East Dump Complex = 55,000,000 tons

d) time to move material from each respective area

West Dump Complex = 4,144 tons/hour (FPC estimated)
East Dump Complex = 3,015 tons/hour (FPC estimated)

e) haulage costs per tons of material

West Dump Complex = $ 0.297 / ton (FPC estimated)
East Dump Complex = $ 0.412 / ton (FPC estimated)

Using the information listed on the previous page, the total cost of the complete backfill alternative has been estimated below:

($0.297/ton) * (194,000,000 tons) + ($0.412/ton) * (55,000,000 tons) = **$80,278,000**

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APPROACH #2 : Quick and Generic Estimation of Backfilling Costs

The following information has been taken from the Caterpillar handbook (Edition 26). Although GSM does not have a complete fleet of Caterpillar equipment, CAT equipment of similar cost and size will be replaced where necessary.

Equipment Specifications

Equipment	Cost per Hour	Adjusted Cost per Hour*	Description
992D	$125.00	$187.50	loader w/standard bucket, spade-edge teeth
785B	$102.00	$153.00	150 ton haul truck
D10N	$106.00	$159.00	dozer
16H	$45.00	$67.50	grader
773B	$60.00	$90.00	fitted water truck (approx. same hourly cost)

*All costs were adjusted by 50% to include interest, insurance, taxes, and operator wages

General Variables

Mechanical Availability = 82%
Material Density = 3,850 lb/yd^3 (assume as an average for all mine material)

992D-Production Rate

bucket capacity = 11.7 yd^3 (struck)
= 14.0 yd^3 (heaped)
bucket fill factor = 100%

# of buckets to fill 785B:

$$\frac{\text{150 ton/load}}{\text{11.7 yd}^3\text{/cycle}} \times \frac{\text{2000 lb/ton}}{\text{3850 lb/yd}^3} = 6.7 \Rightarrow 6 \text{ cycles/load}$$

time to fill trucks: positioning time = 72 s
6 cycles => (18.5 s) x (6 cycles) = 111 s
total time = 3.05 min/truck

production rate:

$$\frac{\text{6 cycles/truck}}{\text{3.05 min/truck}} \times \frac{\text{11.7 yd}^3\text{/cycle}}{\text{1 hr/60 min}} \times \frac{\text{3850 lb/yd}^3}{\text{2000 lb/ton}} \times 82\% = 2{,}180 \text{ tons/hour}$$

daily production rate: 2180 tons/hour x 12 hr/shift = 26,160 tons/shift

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785B-Haul Truck Fleet Sizing

haul cycles: East (haul route; assume return route is of equal time)

Distance (ft)	Rolling Resistance (%)	Grade Resistance (%)	Time (min)
200	3	0	0.25
1180	2	0	0.50
400	2	-10	0.25
1580	2	-7	0.60
3000	2	1.7	1.25
200	3	0	0.25
Total:			*3.10*

haul cycle: West (haul route; assume return route is of equal time)

Distance (ft)	Rolling Resistance (%)	Grade Resistance (%)	Time (min)
200	3	0	0.25
2500	2	4	1.50
200	3	0	0.25
Total:			2.00

size of fleet: East

$$\frac{\underline{6.20\text{ min/haul cycle}}}{3.05\text{ min/truck}} \times \frac{1}{82\%} = 2.48 \Rightarrow 3\text{ trucks/haul cycle}$$

size of fleet: West

$$\frac{\underline{4.00\text{ min/haul cycle}}}{3.05\text{ min/truck}} \times \frac{1}{82\%} = 1.60 \Rightarrow 2\text{ trucks/haul cycle}$$

Total Time

East: 55,000,000 tons x (1 shift / 26,160 tons) x (1 day / 2 shifts) = 1,052 days

West (tons 1 through 55,000,000):

55,000,000 tons x (1 shift / 26,160 tons) x (1 day / 2 shifts) = 1,052 days

West (tons 55,000,000 through 194,000,000; assumes 2 loaders):

139,000,000 tons x (1 shift / 52,320 tons) x (1 day / 2 shifts) = 1,329 days

Total Cost of Project

Description	Tons Moved	Total Cost / hr	Total Time (days)	Overall Cost
East Haul	55,000,000	$810	1,052*	$20,450,880
West Haul	55,000,000	$810	1,052*	$20,450,880
West Haul	139,000,000	$1303.50	1,329	$41,576,436
Total:			*2,381 (6.5 yrs)*	**$82,478,000**

*The primary East and West hauls can occur concurrently (each with a separate loader).

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APPENDIX E

BIOLOGICAL ASSESSMENT

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ATTACHMENT 1 - AGENCY CORRESPONDENCE

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1.0 INTRODUCTION

1.1 Agency Coordination

Federal agencies, in consultation with the U.S. Fish and Wildlife Service (USFWS), are required to ensure that any action they authorize, fund, or carry out will not adversely affect a Federally listed threatened or endangered species. A Biological Assessment is required under Section 7(c) of the Endangered Species Act if listed species or their critical habitat may be present in an area affected by major construction activities.

Golden Sunlight Mines, Inc. (GSM) proposes changes to its plan of operations that require amendment to GSM's State Operating Permit. The Montana Department of Environmental Quality (MDEQ) and the Bureau of Land Management (BLM) are co-lead agencies for the evaluation of anticipated impacts from the proposed Golden Sunlight Mine Project, located approximately 5 miles northeast of Whitehall, Montana. The BLM initially requested a species list applicable to the project area under informal Section 7 consultation with the USFWS. Additional species data also were requested from the Montana Natural Heritage Program (MNHP) and the Montana Department of Fish, Wildlife, and Parks (MDFWP). In response to the initial request for species information, the USFWS provided a list of species that could occur in the proposed project area. The Biological Assessment analysis focused on those species provided in the letter from the USFWS, dated November 21, 1995. Several additional sensitive species that could occur in the Proposed Action area also were analyzed. The correspondence and associated information are provided in Attachment 1 of this Biological Assessment.

1.2 Analysis Summary

This Biological Assessment addresses the potential impacts to Federally listed, Federal candidate, and BLM sensitive species. The USFWS has revised the Federal candidate species lists, omitting the category 2 listing and developing a "candidate" list only. This Notice of Review was published in the Federal Register on February 28, 1996. Since the BLM's current policy manages sensitive species to prevent future Federal listing as threatened or endangered, the BLM continues to protect the previous category 1 and category 2 species in Montana that are not presently included in the USFWS' new candidate listing. These species are currently considered BLM sensitive species. Therefore, this Biological Assessment contains all Federally listed, Federal candidate, and BLM-sensitive species identified by the USFWS and BLM. Chapter 2.0 covers Federally listed species and Chapter 3.0 addresses Federal candidate and BLM sensitive species. The order of analysis encompasses mammals, birds, fish, and plants.

The impact analyses contained in this Biological Assessment incorporated the data presented in the Environmental Impact Statement (EIS). The primary focus for sensitive species has been potential direct, adverse impacts to each species and its associated habitat, and potential secondary impacts to habitat in the project vicinity from proposed mine operations. Table E-1 identifies all species analyzed for the Biological Assessment. A brief impact summary is included for each species, with applicable mitigation measures or environmental protection measures that have been developed or committed to by GSM. The data obtained for this project on species' presence/absence have been incorporated into the current impact analysis, including the summary presented in Table E-1. Detailed descriptions of GSM's proposed activities are included in Chapter II of the EIS.

1.3 Species Not Addressed in the Biological Assessment

The bull trout (*Salvelinus confluentes*), previously a Federal candidate-category 2 species, initially was identified by the USFWS as potentially occurring in the vicinity of the Golden Sunlight Mine. However, initial data on the bull trout's occurrence, range, and/or distribution indicated that the species would not likely occur in the vicinity of the Proposed Action. In Montana, the bull trout is considered to be a possible resident in streams and lakes west of the Continental Divide (USFWS 1995; MDFWP 1996). No perennial streams or other fisheries habitat are present in the Proposed Project area. The bull trout is not known to occur in nearby fisheries habitat, including Whitetail Creek and the Jefferson and Boulder Rivers (MDFWP 1996). For these reasons the bull trout is not analyzed further in this Biological Assessment.

1.4 References

MDFWP. 1996. Personal communication with S. Blazek, ENSR.

Montana Natural Heritage (MNHP). 1995. Response letter regarding special status species that potentially occur in the GSM project area. December 6, 1995.

USFWS. 1995. Personal communication with S. Blazek, ENSR.

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Table E-1

Special Status Species for the Golden Sunlight Mine Project

Common Name	Scientific Name	Status[1]	Habitat Description	Occurrence in the Area
BIRDS				
Peregrine falcon	*Falco peregrinus*	F-E[2]	Cliffs 150 feet or greater in height, close proximity to water where avian prey species are abundant, and isolation from human disturbance	No roosting or nesting habitat; may forage in vicinity
Bald eagle	*Haliaeetus leucocephalus*	F-T	Occur in association with major rivers, lakes, and reservoirs; nesting habitat requires large trees in proximity to open water with an adequate food source of fish and waterfowl	No roosting or nesting habitat; may forage in vicinity
Mountain plover	*Charadrius montanus*	F-C	Flat, shortgrass prairie, and prairie dog colonies in mid- and tall-grass prairie ecosystems; suitable habitat often occurs in intensively grazed areas	Potential habitat exists in Section 16, downstream of diversion, and open meadows east of the proposed disturbance areas
Ferruginous hawk	*Buteo regalis*	BLM-S	Nesting sites include trees, ledges, rock outcrops, and low cliffs in shrub and grassland communities	Not documented in the project area but suitable habitat exists
Northern goshawk	*Accipiter gentilis*	BLM-S	Subalpine fir, Engelmann spruce, Douglas-fir, and ponderosa pine forests; nests in large older trees in dense forest stands	Not likely to occur; occasional foraging or migrating
Trumpeter swan	*Cygnus buccinator*	BLM-S	Open water with appropriate aquatic plants	Documented occurrences near the tailings impoundments

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Table E-1 (Continued)

Common Name	Scientific Name	Status[1]	Habitat Description	Occurrence in the Area
MAMMALS				
Gray wolf	Canis lupus	F-N	Variety of habitat types characterized by secluded denning and rendezvous sites, and sufficient range with minimal exposure to humans	Not likely to occur
Grizzly bear	*Ursus arctos horribilis*	F-T	Alpine and subalpine coniferous forests; minimal exposure to humans	Not likely to occur
Fringed myotis	*Myotis thysanodes*	BLM-S	Variety of vegetation types, including coniferous forest, mixed shrub, sagebrush, riparian, and cropland; roosts in caves, mines, and buildings	Known to occur
Pale Townsend's big-eared bat	*Corynorhinus townsendii pallescens*	BLM-S	Desert shrublands, coniferous forest, and mixed grass prairies; roosts in trees, caves, and man-made structures; hibernacula requires stable temperatures	Known to occur
Western small-footed myotis	*Myotis ciliolabrum melanorhinus*	BLM-S	Woodlands and desert communities, rocky areas; roosts in caves, abandoned buildings, under rocks, in crevices, and under pine bark	Unknown occurrence
Long-eared myotis	*Myotis evotis*	BLM-S	Coniferous forests and mixed woodlands, 6,000 to 9,000 feet; roosts in caves, mine tunnels, lava beds, and buildings	Unknown occurrence
Long-legged myotis	*Myotis volans*	BLM-S	Ponderosa pine and mixed conifer; roosts in caves, man-made structures, and rock crevices	Unknown Occurrence
Spotted bat	*Euderma maculatum*	BLM-S	Cliffs near perennial water and other habitats, including riparian, piñon-juniper, woodlands, and ponderosa pine forest; roosts in crevices and cracks in cliffs or under loose rocks	Unknown Occurrence
Yuma myotis	*Myotis yumanensis*	BLM-S	Desert grassland, woodland, and riparian areas from 4,000 to 7,000 feet; roosts in buildings, caves, and crevices	Unknown Occurrence

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Table E-1 (Continued)

Common Name	Scientific Name	Status[1]	Habitat Description	Occurrence in the Area
PLANTS				
Ute ladies'-tresses	*Spiranthes diluvialis*	F-T	Perennial orchid associated with moist soils in wet or mesic meadows	Not likely to occur

Sources: MNHP 1995; USFWS 1995.

[1] **Federal:**

F-E	Federally listed as endangered: A species in danger of extinction throughout all or a significant portion of its range.
F-T	Federally listed as threatened: A species likely to become endangered within the foreseeable future through all or a significant portion of its range.
F-C	Candidate: Sufficient information on biological vulnerability exists to support proposals to list as endangered or threatened species.
BLM-S	Formerly Candidate - Category 2: The USFWS has discontinued the designation of Category 2 species as candidates for listing (Federal Register: February 28, 1996. Pages 7595-7613).
F-N	Nonessential: Population classified as experimental and nonessential for the designated recovery area.

[2] Currently proposed to be delisted; final decision is pending.

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2.0 FEDERALLY LISTED SPECIES

2.1 Gray Wolf

2.1.1 Status and Distribution

The gray wolf (*Canis lupus*) is identified by some taxonomists as having up to 32 subspecies (Mech 1970); 24 of these subspecies once inhabited North America. The Northern Rocky Mountain wolf (*Canis lupus irremotus*), considered a subspecies, was listed as endangered by the Secretary of the Interior in 1973 (38 Federal Register 14678, June 4, 1973). The entire species was listed as endangered throughout the lower 48 states, except Minnesota, in 1978 (43 Federal Register 9612, March 9, 1978) because of the general trend among taxonomists to recognize fewer subspecies of wolves, and because enforcement problems for protection of the individual subspecies were likely to be encountered (USFWS 1987).

Historically, the Northern Rocky Mountain wolf occurred in all but the northeastern third of Montana (Hall and Kelson 1959). Wolf control efforts in the late 1800s and early 1900s decimated the species, and by the 1920s the few wolves remaining in the western United States probably were limited to wild areas within the National Parks and Forests (USFWS 1987). Currently, both confirmed and unconfirmed sightings of wolves occur throughout the northern Rocky Mountains, primarily within Montana and Idaho. Sporadic reports of individuals also occur in Washington and Wyoming (USFWS 1987). The number of individual wolves and active wolf packs are continually changing, along with their occupied territories.

Three recovery areas have been identified by the Northern Rocky Mountain Wolf Recovery Plan (USFWS 1987) to secure and maintain a minimum of 10 breeding pairs of wolves in each of the 3 recovery areas for a minimum of 3 successive years. These areas include northwest Montana, central Idaho, and the Greater Yellowstone Area.

In 1994, the USFWS approved a plan to establish nonessential experimental wolf populations in Yellowstone National Park and central Idaho (59 Federal Register 60252, November 22, 1994). Rules published in the Federal Register designate gray wolves in each designated recovery area as "nonessential experimental populations" under section 10(j) of the Endangered Species Act. The following provisions for wolf management are included in the rules:

- Wolves designated as nonessential experimental that are within the boundaries of any unit of the National Park or National Wildlife Refuge systems are treated as *threatened* species;

- Wolves designated as nonessential experimental that are not within units of the National Park or National Wildlife Refuge systems but are within the boundaries of a nonessential experimental population area treated as *Federally proposed* species (i.e., proposed for Federal listing); and

- Wolves occurring outside nonessential experimental population areas retain their *endangered* status.

The experimental population for the Yellowstone region encompasses the state of Wyoming, a portion of southeastern Idaho east of Interstate 15 (I-15), and a portion of Montana east of I-15 and south of the Missouri River. The Golden Sunlight Mine falls within the Yellowstone experimental population area; therefore, any wolves that may occur in the vicinity of the mine would be classified as Federally proposed.

2.1.2 Life History and Habitat Requirements

Wolves have occupied nearly all habitat types except for true deserts (Mech 1970; Pimlott 1975). Habitat for wolves is defined as including: 1) an adequate year-round prey base of ungulates and alternate prey species, 2) suitable and somewhat secluded denning and rendezvous sites, and 3) sufficient range with minimal exposure to humans (USFWS 1987).

The basic unit of wolf populations is the pack, which is typically a cohesive group of two or more individual wolves traveling, hunting, and resting together throughout the year (Mech 1970). Most packs include a pair of breeding adults (alpha pair), pups, and often yearlings and/or extra adult wolves (Murie 1944; Fuller and Novakowski 1955; Mech 1970). The size and location of a pack's territory may be stable or shifting (Mech 1973; Haber 1977; Carbyn 1980; Fritts and Mech 1981), and wolves associated with a pack often exhibit a certain pattern of individual movement within the territory during the year (Mech 1970), depending on factors such as prey availability, season, and breeding activities (USFWS 1987). The breeding season occurs from late January through April, with wolf pups arriving in late March to May following a 63-day gestation period (Woolpy 1968; Mech 1970). Litter sizes of wolves generally range from four to seven (Mech 1970).

Rendezvous sites are specific resting and gathering areas occupied by wolf packs during summer and early fall, after the whelping den has been abandoned. The first rendezvous site is often located within 1 to 6 miles of the whelping den, and a succession of sites are used by the pack until the pups are mature enough to travel with the adults (from September to early October) (USFWS 1987).

Most of the research on wolf-prey relations indicates that wolves usually do not deplete their prey populations (Murie 1944; Mech 1970); however, wolf predation may be a factor in ungulate populations in certain areas (Mech and Karns 1977).

2.1.3 Endangerment Factors

According to Young and Goldman (1944) and Mech (1970), the population decline of the eastern timber wolf that occurred within the eastern United States was a result of: 1) intensive human settlement, 2) direct conflict with domestic livestock, 3) a lack of understanding of the wolf's ecology and habits, 4) human fears and superstitions, and 5) the control programs designed to eradicate the species. These factors caused the decline in all the wolf populations within the United States, including those located in the northern Rocky Mountains. Parallel to the eastern timber wolf, land development, habitat loss, poisoning, trapping, and hunting are the primary factors related to the decline of the gray wolf populations located in the northern Rocky Mountains (USFWS 1987).

The expansion of human settlements has ultimately eliminated the wolf from all but remote areas within the contiguous 48 states, and within these areas wolf sightings are predominantly composed of lone or transient individuals. A few locations, primarily National Parks and Forests, currently could support a viable wolf population. Although maintenance and improvement of suitable habitat may be the key long-term factors in wolf conservation, an important element limiting wolf recovery in the northern Rocky Mountains is human-induced mortality (USFWS 1987). Because depredation by wolves on livestock has been the fundamental reason for the virtual extermination of wolves in the western United States, wolf recovery in certain areas will depend, in part, upon enlightened management that recognizes and addresses the ecological, ethical, and economic aspects of the relationship and overall public information and education.

2.1.4 Presence in the Project Area

The three recovery areas identified for the Northern Rocky Mountain wolf subspecies include northwest Montana, central Idaho, and the Greater Yellowstone area (USFWS 1987). Wolves released in Yellowstone National Park as part of the current reintroduction efforts have been ranging northward from the Park, and have been reported in the vicinity of Emigrant, Montana, approximately 80 miles southeast of the mine. Another wolf has been reported between Boulder and Deerlodge, Montana, approximately 50 miles northwest of the Mine (Fontaine 1996). These sightings represent the closest known recent wolf occurrences in the project vicinity. Currently, no pack activity, natal denning areas, or transient wolves are known to occur in the vicinity of the Golden Sunlight Mine (WESTEC 1995; Fontaine 1996). Although transient wolves would be more likely to follow corridors characterized by dense cover and less human development, an occasional transient wolf could occur in the mine vicinity. Wolf populations are anticipated to increase throughout Montana as relocation efforts continue (Fontaine 1996).

2.1.5 Impact Evaluation

Although gray wolf populations may be expanding northward from Yellowstone National Park, no wolf sightings have been reported within 45 to 50 miles of the Golden Sunlight Mine. No project-related impacts to the gray wolf would be anticipated from the proposed mine expansion, due to: 1) lack of cover, 2) lack of individual occurrences in the project area and, 3) no pack activity or natal denning areas are currently known to occur in the project vicinity. Therefore, due to the gray wolf's preference for seclusion (e.g., cover) and minimal exposure to humans, the species is unlikely to inhabit the immediate mine vicinity during active mining operations.

Based on existing agency data, habitats associated with the mine area, and known wolf locations, the BLM has determined that the proposed Golden Sunlight Mine project would not affect the gray wolf.

2.1.6 References

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2.2 Grizzly Bear

2.2.1 Status and Distribution

The grizzly bear (*Ursus arctos*) was Federally listed as threatened in 1975, pursuant to the Endangered Species Act of 1973. Two subspecies of brown bear occur in North America; these include the grizzly bear (*U. a. horribilis*) located on the North American mainland and the Kodiak bear (*U. a. middendorffi*) located on Kodiak, Shuyak, and Afognak Islands (Rausch 1963).

Historically, the grizzly's North American range extended from Ontario, Canada, westward to the California coast and south into Texas and Mexico (Herrero 1972; Storer and Tevis 1955).

Between 1800 and 1975, grizzly bear populations in the United States declined from an estimated 100,000 to less than 1,000 individuals (USFWS 1993). Livestock depredation control, habitat deterioration, commercial trapping, and sport hunting were the leading causes of these declines (Martinka 1976). Conflicts between bears and livestock were common during the settling of the west (Bailey 1931), and the westward push of ranching, farming, fur trapping, and mining interests further increased the pressure on the Great Plains grizzly populations, which were extirpated by the early 1900s (Wright 1909). Logging and recreational development added to the man-induced mortality of the grizzly bear, as the mountainous areas were settled (USFWS 1993).

Currently, five regions within the conterminous 48 states contain grizzly bear populations, including the Northern Continental Divide in Montana, Cabinet/Yaak in Montana, Selkirk Mountains in Idaho and Washington, North Cascades in Washington, and Bitterroot ecosystem in Idaho (USFWS 1993). Population estimates for these areas total less than 1,000 bears.

2.2.2 Life History and Habitat Requirements

The grizzly bear has a broad range of habitat tolerance. Typical habitat is characterized by contiguous, relatively undisturbed mountainous areas with a high level of topographic and vegetative diversity.

The grizzly bear is individualistic in behavior and typically a solitary wanderer. Except when caring for young or during the breeding period, grizzlies maintain individual patterns of behavior (USFWS 1993). This species is relatively long-lived, with an average life span of 25.5 years for both sexes (Craighead and Craighead 1974).

Age of sexual maturity and litter size may vary, depending on the individual's nutritional state (Herrero 1978; Russell et al. 1978). Both male and female grizzlies reach sexual maturity at 4.5 years of age. Mating occurs from late May through mid-July, peaking in mid-June. Female grizzlies give birth to the young within the den around February 1. Litter sizes range from one to four, with the a[illegible]ing two cubs (Craighead and Craighead 1972). The cubs stay with the mother and are [illegible] either as yearlings or 2-year-olds. They then disperse as subadults (USFWS 1993).

The home ranges of adult grizzlies frequently overlap, with the home range of adult males generally found to be larger than that of adult females (Servheen and Lee 1979). Grizzly bears hibernate from October/November to March/May (Craighead and Craighead 1972). Den locations are typically found at higher elevations on steep slopes. After leaving the den, bears move considerable distances from high elevations to lower elevations to reach available food sources (USFWS 1993).

Grizzly bears are typically opportunistic feeders and will use a variety of food sources. Depending on the habitat area, grizzlies will forage on berries, tubers and roots, forbs, small mammals, ungulates, and carrion (Hamer 1974; Servheen and Lee 1979). Forage high in protein and carbohydrates is especially critical following hibernation, when food resources are low and energy requirements are high (USFWS 1993).

2.2.3 Endangerment Factors

The decline of the grizzly bear within North America is attributable to its persecution from man and loss of habitat through the exploration and settlement of its historic range. The expansion of human settlements has ultimately eliminated the grizzly from all but remote areas within the contiguous 48 states, resulting in the isolation of small subpopulations. Loss and fragmentation of natural habitat is particularly relevant to the management and survival of grizzly bears. These animals require extensive home ranges to provide the amount of resources needed. In addition, their low densities, low reproductive potential, individualistic behavior, and utilization of riparian habitat (also used extensively by man) cause this species to be vulnerable to possible extirpation (USFWS 1993).

Currently, nearly 95 percent of the land occupied by grizzlies is state or Federally owned, and much of that land is maintained as multiple-use. Grizzly bears face continued habitat destruction, human disturbances, and direct mortality as man/bear encounters increase.

2.2.4 Presence in the Project Area

Three of the five distinct grizzly bear ecosystems occur within the state of Montana. These include the Cabinet/Yaak, Northern Continental Divide, and Yellowstone populations. The Yellowstone ecosystem, which is closest to the Golden Sunlight Mine, consists of approximately 9,500 square miles of mountainous terrain in and surrounding Yellowstone National Park. Trout (1988) reported that grizzly bear sightings in the Tobacco Root Mountains and Gravelly Range may indicate that the Yellowstone population is expanding. Unconfirmed grizzly bear sightings have been reported in the Elkhorn Mountains approximately 50 miles northeast of the mine between the communities of Boulder and Helena.

Due to the existing level of development in the Jefferson River Valley, the open terrain, and the lack of suitable travel corridors between established recovery areas, it is unlikely that grizzly bears will naturally reestablish populations in the mine vicinity. However, it is possible that an occasional transient grizzly bear could occur in the vicinity of the proposed project.

2.2.5 Impact Evaluation

Since grizzly bears are not known to occur in the vicinity of the Golden Sunlight Mine, no direct impacts to the grizzly would be anticipated from the Proposed Action. Indirect effects would be limited to the loss of potential hunting/foraging habitat, if the grizzly populations were to expand. However, potential habitat impacts would be considered insignificant due to: 1) the open terrain and lower-elevation of the mine site is not considered optimal habitat for the grizzly bear; 2) more secluded habitat located outside the immediate mine vicinity would more likely be utilized by transient bears; and 3) grizzlies tend to avoid areas of human activity, such as occurring in the Jefferson River Valley. For these reasons, the BLM has determined that continued mining at the Golden Sunlight Mine would not affect the grizzly bear.

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2.3 Peregrine Falcon

2.3.1 Status and Distribution

The American peregrine falcon (*Falco peregrinus anatum*) is currently Federally listed as endangered, but has been proposed to be delisted (i.e., removed from the Federal list). The arctic peregrine falcon (*F. p. tundrius*) was delisted in 1994; however, migrants are still protected under the similarity of appearance provision of the Endangered Species Act and the Migratory Bird Treaty Act.

Historically, the American peregrine falcon ranged from Canada and Alaska south to Mexico. Reintroduction and management efforts have re-established nesting peregrine falcons in many areas of the western United States. The main objective of the American Peregrine Recovery Plan for the Rocky Mountain/Southwest Region is to monitor and protect peregrine populations. Efforts to augment the population are concentrated in the central Rocky Mountain states (USFWS 1984).

2.3.2 Life History and Habitat Requirements

The peregrine falcon typically nests on cliffs in close proximity to water sources where avian prey species (e.g., passerines, shorebirds) are abundant. Habitat requirements typically include: 1) an inaccessible nest site, 2) an adequate prey base, 3) proximity to water, and 4) isolation from human disturbances (Haynam and Sumner 1977; USFWS 1984). Peregrine nest sites are often located on cliff faces 150 feet or greater in height, with an overhanging ledge or rock outcrop (USFWS 1984). The nest typically consists of a scrape on the rock substrate (Enderson and Craig 1974; Cade 1960).

Peregrine falcons mature at about 2 to 3 years of age. Adults typically return to the breeding areas in mid-March and exhibit a strong site fidelity, although alternative nest sites also may be used within an individual breeding territory (Fyfe et al. 1976). The female lays a clutch of three to four eggs in April. Both the male and female may incubate, although the female is the primary incubator. The incubation period is approximately 33 days. Both adults provide food for the nestlings. Young generally fledge in June or July and are soon independent from the adults (USFWS 1984).

Peregrine falcons typically forage within 10 miles of a nest site, along water sources (USFWS 1984). However, studies have indicated that breeding birds may travel up to 31 miles from active eyries in Colorado to feed (Craig 1994). Preferred foraging areas include marshes, lakes, rivers, and wet meadows (Porter and White 1973).

2.3.3 Endangerment Factors

A number of factors have contributed to the decline of the peregrine falcon within the last century. The predominant factor is the thinning of peregrine eggshells from pesticide poisoning. Other influences include: 1) taking of falcon nestlings by falconers, 2) shooting, 3) effects to eyries from increased human presence and associated disturbances, and 4) habitat loss. The loss of associated riparian habitat is particularly applicable and can result in a reduction in prey availability (Herbert and Herbert 1965; Peakall 1974; Thelander 1978).

Historically, the marked decline in active peregrine eyries and the greatly reduced productivity of this species in the United States have primarily been due to the bioaccumulation of chemical residues and habitat loss. A metabolite of DDT (DDE) has been proven to cause eggshell thinning, although other chemicals and pesticides also may be a factor in unsuccessful reproductive efforts (USFWS 1984).

Due to the decreased use of these pesticides in North America, the breeding success has improved for a number of birds, including the peregrine falcon. Reintroduction (hacking) programs initiated throughout the United States and further protection of the individual birds and their habitat also have provided support for the populations, resulting in increased peregrine numbers. These improvements have led the USFWS to delist the arctic subspecies and propose to delist the American subspecies, as discussed in Section 2.3.1. However, habitat loss and disturbance continue to be a factor in the recovery of this species.

2.3.4 Presence in the Project Area

Both subspecies of peregrine falcons are known to migrate through the region and are most likely to occur along the Jefferson and Boulder River Valleys. Nesting falcons may occupy ridges and bluffs adjacent to the Proposed Action area. Observations indicate that peregrines may nest within a few miles of the mine. However, raptor nest searches were conducted throughout the study area in all habitat types during April and May 1994, and no peregrine falcons were documented. In addition, no peregrine nests were discovered during subsequent surveys of potential habitat in the general mine vicinity, including Doherty Mountain, located approximately 4 miles east of the mine (WESTEC 1995). Although peregrines likely forage along the Jefferson and Boulder Rivers, the riparian habitat that occurs near the Golden Sunlight Mine project would be considered marginal for foraging falcons.

2.3.5 Impact Evaluation

During project operation, foraging peregrines would avoid the limited riparian areas near the mine site, but potentially would forage outside the immediate mine area. The marsh, lake, river, and wet meadow habitat types preferred by foraging peregrines do not occur within the Proposed Action area, and the ephemeral drainages located in and adjacent to the mine area do not represent optimal foraging habitat for this species, as discussed above. However, peregrines feeding over the Jefferson and Boulder Rivers could follow tributary drainages from the rivers up to the mine site, and may occasionally occur in the mine vicinity.

Based on existing agency information regarding the peregrine falcon, no designated critical habitat, occupied eyries, or optimal foraging areas are known to occur in areas that would be directly affected by the Proposed Action. In addition, no peregrine falcon activity or signs were observed during the wildlife reconnaissance conducted between November 1993 and August 1995. Based on this information, the BLM has determined that continued mining at the Golden Sunlight Mine would not affect the peregrine falcon.

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2.4 Bald Eagle

2.4.1 Status and Distribution

The bald eagle (*Haliaeetus leucocephalus*) was recently downlisted to Federally threatened throughout the lower 48 States from endangered status (USFWS 1995). The bald eagle's breeding range formerly included most of the continent; the species historically nested in areas where suitable habitat occurred. The eagle's winter range includes most of the breeding range but extends predominantly southward from southern Alaska and southern Canada (USFWS 1986).

Both breeding and wintering eagles are found in Montana. The majority of breeding eagles in Montana occurred in the western portion of the state. Wintering eagles are widely scattered, and occur in association with major rivers, lakes, and reservoirs. Areas of high use include Flathead Lake, the Yellowstone River, and the upper Missouri River. Large numbers of eagles follow spring migration routes along the Yellowstone and Shields Rivers (USFWS 1986). Maintenance and improvement of wintering bald eagle habitat is one objective of the Bald Eagle Recovery Plan for the Pacific Population (USFWS 1986).

2.4.2 Life History and Habitat Requirements

Bald eagles normally reach breeding age at about 5 years, which roughly coincides with full adult plumage (Hancock 1973). The breeding season of the bald eagle varies with latitude. Nesting activities occur as early as November, but typically take place in February or early March and include courtship flights, nest repair, and nest building. Nests are usually located in multi-storied trees; optimum nesting habitat includes proximity to open water that provides an adequate food source, large nest trees with sturdy branches at sufficient height, and stand heterogeneity. Egg laying and incubation usually begin in March, lasting approximately 35 days. One to four eggs (average two) are laid (Brown and Amadon 1968). The period from hatching to fledging is about 10 to 13 weeks, with a post-fledging period of 3 to 10 weeks (Todd 1979).

Bald eagles migrate south from breeding areas between September and December and generally winter as far north as open water and food are available. The major habitat components on wintering grounds include a food source and suitable trees for diurnal perching and night roosting. Wintering bald eagles may gather in large aggregations and share communal roosts, diurnal perches, and feeding areas. Eagles are attracted to large bodies of water (Cooksey 1962; Ingram 1965), but may use arid valleys as well (Edwards 1969).

Food availability is probably the single most important factor influencing winter eagle distribution and abundance (Steenhof 1976). Waterfowl, particularly dead or crippled individuals, are often taken when fish are not readily available (Shickley 1961; Spencer 1976). In some regions, carrion is an important food source. Live mammals, such as mice, jackrabbits, and gophers also are taken (USFWS 1986). Eagles will maximize alternate food sources as availability changes.

Perches are an essential element in bald eagles' selection of foraging areas, since they are necessary for hunting and resting (Stalmaster and Newman 1979). Perch sites must be in open view of potential food sources. Night roost sites offer protection from predators and a degree of protection from inclement weather. Large, live trees that occur in sheltered areas are preferred (Lish and Lewis 1975). Eagles may roost individually or in small groups, and roosts can be used for successive years. Eagles generally leave the roost for feeding areas in the early morning and return in the evening, except during severe weather when they may remain at the roost throughout the day.

2.4.3 Endangerment Factors

The decline in eagle numbers is attributed to loss of habitat; human disturbance; illegal shooting, poisoning, and trapping; electrocution from power lines; lead contamination of prey; and pesticide poisoning. Habitat loss for both breeding and wintering bald eagles has been associated with land development and human activity in breeding and wintering habitats. Human activity near a nest site during the breeding season can result in nest abandonment and lowered reproductive success.

Electric powerlines can pose a threat to bald eagles and other raptors, depending on the line's size and configuration. Overall, bald eagle collisions with powerlines appear to occur with less frequency than electrocutions. However, in specific areas where bald eagles concentrate, transmission lines can represent a collision threat (USFWS 1986). Secondary poisoning from eating lead-contaminated prey, particularly in wintering areas where eagles feed on crippled ducks and geese, and feeding on poisoned carcasses also can reduce eagle numbers (Jacobson et al. 1977; USFWS 1986).

In the past, direct and indirect effects of organochlorine pesticides severely impacted bald eagle populations (Bailey 1984). However, as discussed for the peregrine falcon, the decreased use of these pesticides in North America has resulted in greater breeding success for bald eagles. This increased breeding success, combined with the species protection, has resulted in the downlisting of the species by the USFWS, as discussed in Section 2.4.1.

2.4.4 Presence in the Project Area

In Montana, the majority of nesting bald eagles occur in the western part of the state. Wintering eagles in the state are widely scattered and occur in association with major rivers, lakes, and reservoirs (USFWS 1986). Because of the upland habitats occurring in the mine vicinity and the species' close association with water, it is unlikely that birds would nest or roost in or near the mine site. No bald eagle nests have been documented near the study area (WESTEC 1995). However, bald eagles may migrate and overwinter along the Jefferson and Boulder River Valleys (WESTEC 1995) and one individual was observed in the immediate mine vicinity (ENSR 1995). Potential foraging habitat with suitable prey species (e.g., small mammals) occur in and adjacent to areas that would be affected by the proposed project.

2.4.5 Impact Evaluation

No habitat that would support roosting eagles would be impacted by the proposed project. Potential hunting/foraging habitat would be impacted; however, as discussed for the peregrine falcon (Section 2.3.5, Impact Evaluation), the area affected by the Proposed Action does not represent optimal hunting/foraging habitat for the bald eagle.

Based on the available agency information, available habitat, and documented eagle use of the Proposed Action area, the BLM has determined that continued mining at the Golden Sunlight Mine would not affect the bald eagle.

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2.5 Ute Ladies'-Tresses

2.5.1 Status and Distribution

The Ute ladies'-tresses (*Spiranthes diluvialis*) is Federally listed as threatened. This plant primarily occurs in areas where the vegetation is relatively open, but not overgrazed. Ute ladies'-tresses populations typically occur in relatively low elevation riparian meadows. The recent discovery of the Ute ladies'-tresses near the mine represents a major increase in the known range of the species. It has been collected recently or historically from a limited area spanning Arizona, Colorado, Nevada, Utah, and Wyoming (Heidel 1996).

2.5.2 Life History and Habitat Requirements

Ute ladies'-tresses is a perennial, terrestrial orchid characterized by 3 to 15 small white- or ivory-colored flowers clustered into a spike arrangement at the top of 8- to 20-inch stems. It typically blooms from late July through September, occasionally into September and early October (Sheviak 1984; Coyner 1990; Jennings 1989). This species is endemic to moist soils in wet or mesic meadows near springs, lakes, or perennial streams.

This plant appears to have a very low reproductive rate under natural conditions (Coyner 1990). The Ute ladies'-tresses is similar to other orchid species in that it takes 5 to 10 years to reach reproductive maturity, and reproductively mature plants do not flower every year.

2.5.3 Endangerment Factors

The Ute ladies'-tresses is threatened primarily by habitat loss and modification, which has been prevalent throughout the western United States. In addition, its small population and low reproductive rate also make it vulnerable.

2.5.4 Presence in the Project Area

The Ute ladies'-tresses is known to occur in the Piedmont Swamp wetland basin near Whitehall, Montana (Heidel 1995). Suitable habitat for this species does not occur within the proposed disturbance area or in the vicinity of the Golden Sunlight Mine project. No Ute ladies'-tresses were observed during vegetation surveys conducted in 1994 and 1995 (GSM 1995a).

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3.0 FEDERAL CANDIDATE AND BLM-SENSITIVE SPECIES

In addition to the two BLM sensitive bat species identified by the USFWS as occurring in the project area and addressed in detail below, five other sensitive bat species may occur. These five species include the western small-footed myotis, long-eared myotis, long-legged myotis, Yuma myotis, and spotted bat. It is currently unknown whether these five bat species may occur in the project area. Their associated habitat descriptions are listed on the summary table in Section 1.2 of this Biological Assessment (see Table E-1), and these five species are addressed further in Section IV.F in the EIS.

The overall impact analysis for sensitive bat species focuses on the potential direct impacts from loss of habitat (e.g., shafts, adits) and potential indirect effects (e.g., noise) to roost concentrations. No known maternity colonies, hibernacula, or bachelor roosts have been documented in the mine area; however, bats may be affected, depending on habitat associations and potential presence. These issues are addressed below for both bat species documented in the mine vicinity and in Section IV.F of the EIS for the other five sensitive bats identified by the BLM.

3.1 Fringed Myotis

3.1.1 Status, Habitat Requirements, and Endangerment Factors

The fringed myotis (*Myotis thysanodes*) is currently a BLM-sensitive species. This bat species is one of the larger of the genus *Myotis*. Fringed myotis are found in western North America from British Columbia, Canada, south to Veracruz and Chapas, Mexico (O'Farrell and Studier 1980).

The fringed myotis is reported to occupy a range of habitats, including ponderosa pine, oakbrush, shrublands, and riparian. This species also forages in a variety of other habitats (Hoffmeister 1986; O'Farrell and Studier 1980; Findley et al. 1975; Fitzgerald et al. 1994).

Fringed myotis are largely colonial and prefer to use caves, mines, and old buildings as roosting and breeding sites (Bailey 1971; Findley et al. 1975; O'Farrell and Studier 1980). Roost sites are apparently occupied in a transient fashion during the night (Hoffmeister 1986).

A considerable variation in parturition of females has been recorded within colonies and between geographically separated colonies. Ovulation, fertilization, and implantation occurs in the spring, followed by a gestation period of 50 to 60 days (O'Farrell and Studier 1980). Pregnant females have been recorded from mid- to late June, lactating females taken from mid-July to late August, and young of the year from early August to early September (Findley et al. 1975). Bachelor roosts are generally located within the vicinity of the maternity colonies (O'Farrell and Studier 1980).

Fringed myotis are known to migrate, although little is known about the species' movements. It is speculated that fall migrations involve short distances to lower elevations or more southern areas where the bats are periodically active during the winter. Spring migration into a maternity colony is rapid, occurring from mid- to late April (O'Farrell and Studier 1980).

Fringed myotis are agile fliers, capable of nearly vertical flight, allowing this species to take off and land from a flat surface (Findley et al. 1975). It is a foliage gleaner within vegetative canopies. Fringed myotis are nocturnal and typically leave the roost shortly after sunset, returning within approximately 4 hours. Females from maternity colonies tend to forage for longer periods, departing the roost at sunset and returning near dawn (O'Farrell and Studier 1980).

This species is easily disturbed by human presence. Prior to parturition, females become even more secretive and are virtually impossible to approach (O'Farrell and Studier 1980).

3.1.2 Presence in the Project Area

Potential roosting and foraging habitat for the fringed myotis exists within the project area, as well as surrounding terrain. Although this myotis species could occupy and utilize the habitat types located in and near the project area, the grassland and savannah communities prominent throughout the project area would not be considered optimal foraging habitat for these gleaners. Because this bat species occupies caves, mines, and buildings for roosting, individuals may be present within the abandoned shafts and adits that occur throughout the mine area. Until field surveys are conducted during the appropriate seasons to determine whether these mine components support maternity colonies or hibernacula, it is unknown whether the fringed myotis occurs within the area proposed for the Golden Sunlight Mine project.

3.1.3 Impact Evaluation

Potential disturbance to roosting bats and loss of roosting and foraging habitat may occur from mine construction and operation, resulting in both direct and indirect impacts to the fringed myotis, if present in the project area. In the event that mine development and expansion were to affect concentrations of roosting bats, adverse impacts to both individual bats and established colonies could result. Direct loss of roosting habitat could result in both direct mortality and displacement of bats, depending on the season of disturbance. Increased noise and vibrations from blasting at the mine could also result in colony abandonment and displacement. Finally, vibrations from blasting could affect the integrity of existing underground openings (e.g., adits, drifts, shafts), possibly resulting in the loss of the colony or disruption of air flow into roost sites. Adequate ventilation can be critical to roosting bats, particularly for hibernacula, which typically require constant and stable air temperatures.

The fringed myotis may be adversely affected by mining activities and low quality water from both existing and proposed mine operations. Loss of available water at naturally occurring seeps and springs in the vicinity of the mine also could adversely impact resident bat species, depending upon the water quality and actual flow reductions. The loss of available water could decrease the amount of foraging habitat for this species.

To minimize potential impacts to roosting bat species, an inspection or survey of existing mine shafts would be conducted prior to the initiation of mining activities to determine bat presence and occupancy. GSM would notify the BLM prior to closing any shafts, adits, or man-made structures on BLM-managed land during the mine operations. BLM would determine whether additional protection measures would be warranted to prevent impacts to BLM sensitive bat species that may inhabit these areas.

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3.2 Pale Townsend's Big-Eared Bat

3.2.1 Status, Habitat Requirements, and Endangerment Factors

The pale Townsend's big-eared bat (*Corynorhinus townsendi pallescens*), is a BLM-sensitive species. This subspecies occurs throughout western North America (Hall 1981). In Montana, the subspecies' distribution extends into the state's central and southwestern regions (ISCE 1995).

The Townsend's big-eared bat occupies habitats ranging from semidesert shrublands, piñon-juniper woodlands, and open montane forests. Where this species occurs on the Great Plains, it is restricted to deciduous woodlands near suitable caves and rock outcrops (Fitzgerald et al. 1994).

Townsend's big-eared bats are found diurnally in caves, rock shelters, or mine tunnels, but at night they often rest in abandoned buildings (Fitzgerald et al. 1994; Findley et al. 1975; Hoffmeister 1986). These bats are insectivorous and glean prey items such as small moths, dipterans, and beetles along the margins of vegetation, over water, and over sagebrush. This bat species is relatively sedentary, moving short distances from both seasonal hibernacula and day roosts. This species may go undetected, due to its seclusion and sensitivity to disturbance, unless roost sites are located (Fitzgerald et al. 1994).

The mating of the big-eared bat is polyandrous, and no pair bond is formed. Breeding takes place in the fall and winter, followed by ovulation in late winter or early spring, and delayed fertilization occurring in the spring (Hoffmeister 1986). Maternity colonies begin forming as early as late April (Hoffmeister 1986). A single young is produced, and by late July, most of the young are able to fly. Females breed as juveniles; males breed as yearlings (Hoffmeister 1986).

Although non-territorial, this colonial species seems to exhibit a high degree of site fidelity, returning annually to the same maternity roost. Selection of warm nursery sites is essential for reproductive success. Hibernacula typically (e.g., caves and mine shafts) maintain low temperatures and moderate to strong air flow (BISON-M 1995). Hibernating Townsend's big-eared bats are sensitive to temperature and humidity fluctuations and may abandon a roost site in response to changes (Fitzgerald et al. 1994).

This species is threatened by habitat loss, vandalism, and disturbance to maternity colonies and hibernacula, primarily by recreationists and cavers. The extreme sensitivity of this species to human disturbance has often resulted in permanent abandonment of a roost or colony site.

Hibernacula with the appropriate temperature and humidity levels are the limiting factors for this bat species.

3.2.2 Presence in the Project Area

Since, the pale Townsend's big-eared bat typically roosts in caves and mine tunnels it may be present within the mine area. As a foliage gleaner, this species also could forage throughout the project area. This species is known to occur in Lewis and Clark Caverns State Park approximately 10 miles southeast of the mine area. However, it is currently unknown to what extent the pale Townsend's big-eared bat may occupy the proposed project area.

3.2.3 Impact Evaluation

Potential impacts to the pale Townsend's big-eared bat parallel those discussed for the fringed myotis in Section 3.1.3 in this Biological Assessment. Both direct and indirect disturbance to roosting bats may occur from mine construction and operation, if this species were present in the project area. The Townsend's big-eared bat would be more susceptible to disturbance than other bat species that may occur in the area. This species would be particularly sensitive to disturbance during hibernation, including possible effects from disruption of air flow into any hibernacula and from noise during mine operation. As discussed in Section 3.1.3, the mitigation measures developed to protect bat species that may occupy the mine area would aid in minimizing the potential effects to this species from the proposed project.

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3.3 Mountain Plover

3.3.1 Status, Habitat Requirements, and Endangerment Factors

The mountain plover (*Charadrius montanus*) is a BLM-sensitive species. Mountain plovers are mainly a species of the high plains and semi-desert regions of the western United States. Its nesting range once extended from northern Montana to central and southeastern New Mexico and west Texas (Terres 1991). The mountain plover's current nesting range is restricted, with small populations breeding only in parts of Montana, Wyoming, Oklahoma, and New Mexico, with a nesting population concentration on the Pawnee National Grasslands in northeastern Colorado (Graul 1975).

Mountain plovers prefer flat, shortgrass prairie and tend to avoid taller grasses and hillsides (Graul 1975). Suitable habitat often occurs in areas intensively grazed. This species also occupies prairie dog colonies, particularly in mid- and tall-grass prairie ecosystems. Migrants occasionally occur on dry mudflats and shorelines of dry reservoirs (Andrews and Righter 1992). Mountain plovers forage in dry short-grass prairies of low scattered bunchgrass, scattered sagebrush, and cactus, feeding primarily on grasshoppers, crickets, beetles, and flies (Ehrlich et al. 1988; Terres 1991). Outside of the breeding season this species may occur in flocks up to several hundred, feeding over alkaline flats, plowed ground, sprouting grain fields, or grazed pastures (Terres 1991).

The mountain plover generally arrives on its nesting range from mid-March through mid-May. Although plover nesting is closely associated with prairie dog colonies or complexes in mid to tall-prairie ecosystems, studies do not indicate that the mountain plover is an obligate nester in these colonies, particularly in areas where livestock are able to provide the necessary vegetative structure typically maintained by the foraging behavior of prairie dogs (USFS 1994).

The plover breeding system is characterized by rapid, multiple clutches often with sequential polyandry. The nest is a slight depression on bare, open ground between hummocks, occasionally amid cacti or scattered shrubs, and often near old cow manure. The nest will sometimes have a slight lining of fine rootlets, dried grasses, and dried manure. The eggs are layed in May, averaging three per clutch. After the female lays the first clutch she abandons the nest, and the male of the pair incubates. She then lays a second clutch and incubates these. Incubation lasts 29 days and the young fledge in 34 days (Graul 1975; Ehrlich et al. 1988; Terres 1991). Brood-rearing habitat includes the characteristics of nesting habitat, but is also thought to include other vegetation types such as taller plant associations and areas of slope varying from flat to 30 percent (USFS 1994).

Mountain plovers typically migrate from their breeding grounds in the Great Plains to wintering grounds located from Texas to California's central valleys (USFS 1994).

Habitat destruction in both winter and summer breeding ranges for the mountain plovers is suspected as a cause of long-term population declines (USFS 1994). Additionally, prior to 1900, the species was subjected to market hunting. The amount of suitable habitat has been drastically reduced, following the conversion of prairie to agricultural cropland. However, the effects of development on the plover have not been well analyzed (Ehrlich et al. 1988; Andrews and Righter 1992). Although mountain plovers use prairie dog colonies for nesting they appear to prefer areas heavily grazed by livestock. This may be a result of high concentrations of predators associated with prairie dog colonies. However, livestock levels must be carefully managed to prevent nest trampling and associated disturbance effects. In addition, brooding habitat with taller plant associations must be available adjacent to nesting areas (USFS 1994). During incubation and brooding, disturbances that prevent the adult from protecting the nest for more than 15 minutes may result in loss of eggs or young, especially during extreme heat (USFS 1994).

3.3.2 Presence in the Project Area

Within the proposed project area, native shortgrass prairie that would support breeding plovers is located in the portion of Section 16 in the permit boundary and downstream of the diversion. Potential habitat also occurs immediately east of the mine in a heavily grazed pasture (Knowles 1996). This species is known to occur in heavily grazed grasslands approximately 2 miles west of the mine (Jurist 1995). Although these areas would be considered potential nesting habitat, no mountain plovers were observed during the Phase 2 wildlife study (WESTEC 1995).

3.3.3 Impact Evaluation

The disturbance of approximately 395 acres of grassland and pastureland from the Proposed Action would reduce the amount of potential breeding habitat for the mountain plover in the vicinity of the project. Although no plover nesting has been documented near the mine area, the Proposed Action would remove this potential breeding habitat for the life of the mine. In addition to the direct habitat loss from mine development and expansion, the mountain plover may be indirectly impacted by increased noise and human presence in and near the mine. Neither of these adverse impacts that may occur from implementation of the Proposed Action or Alternatives would be considered a significant impact because plovers are not likely to nest in areas proposed for disturbance; these areas are not considered optimal habitat for this species.

3.3.4 References

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3.4 Northern Goshawk

3.4.1 Status, Habitat Requirements, and Endangerment Factors

The northern goshawk (Accipiter gentilis) is a BLM-sensitive species. This species is an uncommon resident of the forests of Canada, Alaska, and the northern United States, as well as the forests of the western and southwestern United States. Individual goshawks normally winter in the general vicinity of summer breeding grounds, but they will migrate south in the fall, when the goshawk's cyclic prey base of hares, lemmings, and grouse periodically declines in more northern habitats (Terres 1991).

Goshawks prey on a variety of forest birds and mammals. Important forest features that provide habitat for goshawk prey populations include snags, downed logs, large trees, herbaceous and shrubby understories, small forest openings, and an interspersion of different vegetation structural stages (Reynolds et al. 1992).

Goshawks prefer to nest in large, older trees located in remote blocks of dense large timber (Reynolds 1983; Kennedy 1988). High tree canopy cover and a high density of large trees provide a relatively mild and stable microenvironment for incubation, as well as protection from predators of young goshawks (Reynolds et al. 1992). Nests are usually located within 0.25 mile of water (Shuster 1980; Crocker-Bedford et al. 1988). Nest sites are often reused annually, and some are used intermittently for decades (Reynolds 1983). Many pairs of goshawks have two to four alternate nest areas within their home range, and previously occupied nest areas may be critical for maintaining nesting populations (Reynolds et al. 1992). The average nesting home range size for goshawks is approximately 6,000 acres (Reynolds et al. 1992).

Goshawk populations have declined significantly across its range. This species is thought to be at risk primarily from forest habitat alterations associated with the changes caused by timber harvesting. Habitat alterations that probably limit goshawk populations include: loss of the herbaceous and woody understory necessary for maintaining prey populations; reductions in the amount of large, older trees available for nesting; and increased areas of dense tree regeneration that inhibit aerial foraging. Other factors, such as fire suppression, livestock grazing, drought, and pesticides also may be involved in the decline of this species (Reynolds et al. 1992).

3.4.2 Presence in the Project Area

The northern goshawk would not breed in the open grassland and savannah habitats associated with the mine area. Goshawks would move through the area, either during migration or as they move between nesting and primary foraging areas. This forest species likely occupies the higher elevations to the north and west of the project area, and the mine area would provide secondary foraging habitat. An observation of a northern goshawk was reported for the Golden Sunlight Mine project area; however, this was likely a transient individual.

3.4.3 Impact Evaluation

Based on the lack of potential nesting habitat and the low possibility of impacting foraging birds, no impacts to the northern goshawk would be anticipated from the proposed continued mining at the Golden Sunlight Mine.

3.4.4 References

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3.5 Ferruginous Hawk

3.5.1 Status, Habitat Requirements, and Endangerment Factors

The ferruginous hawk (*Buteo regalis*) is a BLM-sensitive species. This species occurs in the semi-arid regions of the western United States, particularly within the Great Basin and Great Plains (Snow 1974). Associated habitats include sagebrush-grass, piñon-juniper, saltbush-grass, blackbrush, grassland, barren, marsh, mesic meadow, and riparian communities (Dalton et al. 1990).

This species typically nests on rock outcrops, promontory points, low cliffs, and trees along riparian areas (Snow 1974). Nesting habitat consists of communities with isolated trees, woodland edges, buttes, cliffs, and/or grassland with some relief (Jasikoff 1982). Nest territories are occupied between April and July (Dalton et al. 1990). Nest construction commences in early March, with both the male and female participating. Construction activity may occur at several alternative nest sites prior to egg laying (Olendorff 1973). The female lays a clutch of three or four eggs in April, and is the primary incubator. The incubation period is approximately 28 to 35 days (Snow 1974). Young fledge at the age of 38 to 50 days. Fledglings remain in close vicinity to the nest site for several weeks.

Foraging habitat consists of non-forested, nonmountainous areas, such as desert shrub and grassland communities (Jasikoff 1982). Ferruginous hawks are diurnal hunters of mammals, birds, and reptiles. Their diet is less diverse than other hawks; up to 90 percent consists of lagomorphs and rodents (Snow 1974). Habitat requirements for the ferruginous hawk include: 1) a protected nest site, 2) an adequate prey base in close proximity to nest site (Smith and Murphy 1973), and 3) isolation from human disturbance.

The decline of the ferruginous hawk within the western United States is predominantly due to increased human disturbances directly affecting the species' reproductive success, and habitat alteration, resulting in decreased prey base and nest site opportunities (Howard and Wolfe 1976; Jasikoff 1982). With the increasing demand on public lands, human activity in areas supporting nesting pairs of ferruginous hawks has become a limiting factor. Ferruginous hawks are susceptible to disturbance during the courtship and incubation periods, which can cause nest abandonment (Snow 1974). Another prominent factor affecting the ferruginous hawk is habitat loss within its range. Continuing loss decreases the availability of suitable nesting sites, reduces the primary prey populations, and results in increased disturbances to breeding birds (Howard and Wolfe 1976; Jasikoff 1982).

3.5.2 Presence in the Project Area

There are no documented observations of the ferruginous hawk in the mine area. However, this species is known to occur in south-central Montana, and suitable habitat exists in the mine vicinity. Therefore, the ferruginous hawk is likely to occur in the proposed project area.

3.5.3 Impact Evaluation

No direct impacts to the ferruginous hawk would be expected from the proposed project because no nesting birds have been documented in the mine area. Indirect impacts would include some loss of foraging habitat and potential nesting habitat; however, no known nest sites would be disturbed.

3.5.4 References

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3.6 Trumpeter Swan

3.6.1 Status, Habitat Requirements, and Endangerment Factors

The trumpeter swan (*Cygnus buccinator*) is a BLM-sensitive species. This species breeds and nests along the Gulf of Alaska; the Yellowstone-Centennial Valley, which includes Red Rock Lakes National Wildlife Refuge (RRL-NWR); the Grande Prairie area of west-central Alberta; and the Cypress Hills of southern Alberta and Saskatchewan. The Yellowstone-Centennial Valley region of northwestern Wyoming and southwestern Montana provides the most important breeding area for this species in the contiguous United States. In Montana, this species was believed to have utilized extensive breeding areas in the western portion of the state. Trumpeter swans once were distributed over the central west and the Gulf Coast of Alaska, but now are more limited in distribution due to the historical taking of swans and loss of habitat (Belrose 1976).

Trumpeters migrating north generally arrive at breeding and nesting areas in April. Egg laying normally starts in early May and the clutch consists of 3 to 9 eggs. Young generally hatch in mid-June. Trumpeter swans breed and nest only in open waters containing their preferred diet of aquatic plants. They also feed on grain, seeds, freshwater invertebrates, snails, and worms. Trumpeter swans use muskrat or beaver houses and broad beds of marsh plants to build nests (Belrose 1976). The swans uproot plants in a large circle and build the nest in the center, with surrounding open water for good visibility. The nest is approximately 6 to 7 feet in diameter at the base and rises approximately 1.5 feet above the waterline. Trumpeters rely on open bodies of water to provide the aquatic plants that comprise most of their diet.

The status of the United States population of trumpeter swans is improving under current management efforts. Mid-winter swan surveys conducted at RRL-NWR show an increase from 540 in 1970 to 2,936 in 1996 (Gomez 1996). Several populations of swans from the RRL-NWR have been transplanted to Idaho, Wyoming, and Oregon. The preservation of trumpeter swan habitat is integral to the continued existence the species. Other than the direct disturbance of nesting populations, human activities and developments in or near their habitats may have the highest potential to negatively impact trumpeter swan populations in the United States (Belrose 1976).

Winter habitat is especially critical and limiting to trumpeter swans. To survive the severe winters of the Centennial Valley region, the swans require lakes and streams that are rich in aquatic life and do not freeze. Human disturbances such as summer home development and winter recreationists may displace swans from their limited habitat.

3.6.2 Presence in the Project Area

Most trumpeter swans in Montana, including approximately 430 summer residents, are found in the RRL-NWR and the surrounding Centennial Valley (USFWS 1994). The Madison River and associated tributaries are used by trumpeter swans throughout the winter. The Whitehall area is located within the corridor used by trumpeter swans migrating between Canada and eastern Idaho. Ennis Lake, located approximately 36 miles south of Whitehall, is an important staging area for migrating trumpeter swans. The combined U.S. and Canadian populations in the Rocky Mountain Region include approximately 2,900 trumpeter swans (Gomez 1996).

Red Rock Lakes phased out artificial winter feeding in the winter of 1992-93 and numerous swans were transplanted to other areas in Idaho, Wyoming, and Oregon. In addition, the Flathead Indian Reservation is proposing to reintroduce trumpeter swans to northwestern Montana. These factors combine to increase the potential dispersal of swans into other sites, depending on habitat availability.

3.6.3 Impact Evaluation

No trumpeter swan nest sites or foraging areas are known to occur in the vicinity of the Proposed Action. However, the project area is within the migration corridor used by the Rocky Mountain trumpeter swan population, and trumpeter swans have been documented at the mine site during migration periods. In 1995, a total of 8 trumpeter swans were hazed from the tailings impoundment areas, with no reported mortalities (GSM 1996).

GSM has committed to continuing its around-the-clock hazing and monitoring program, described in Chapter II, to protect wildlife at the tailings impoundments. Based on the effectiveness of the continuing hazing program, no adverse impacts to this species in the tailings impoundment areas are anticipated. Under the proposed project, a pit lake would be allowed to form following mine operations. Trumpeter swans could be attracted to and come into contact with poor quality water in the pit lake. Without an effective hazing program, as implemented for the tailings impoundments, adverse impacts to this species could occur in the pit area.

3.6.4 References

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ATTACHMENT 1

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United States Department of the Interior

FISH AND WILDLIFE SERVICE
ECOLOGICAL SERVICES
100 N PARK, SUITE 320
HELENA MT 59601

File: M.02 BLM Headwaters Resource Area (I) November 21, 1995

Merle Good, Area Manager
Bureau of Land Management
Headwaters Resource Area
Box 3388
Butte, MT 59702-3388

Dear Mr. Good:

This is in response to your November 8 letter requesting the Fish and Wildlife Service (Service) provide a list of endangered and threatened species that may occur in the vicinity of the Golden Sunlight Gold Mine expansion.

On November 22, 1994, the Service approved a plan to establish nonessential experimental populations of wolves in Yellowstone National Park and central Idaho. Rules published in the *Federal Register* designate gray wolves in each area as nonessential experimental populations under section 10(j) of the Act. Within the designated nonessential experimental population areas described and depicted in the rules, all gray wolves will be managed in accordance with the provisions outlined the rules which include the following:

a) For section 7 consultation purposes wolves designated as nonessential experimental that are within the boundaries of any unit of the National Park or National Wildlife Refuge systems are treated as a threatened species. As such, the section 7 procedures for listed species would apply to Federal actions within National Parks and National Wildlife Refuges.

b) Wolves designated as nonessential experimental that are not within units of the National Park or National Wildlife Refuge systems but are within the boundaries of the nonessential experimental population area are treated as proposed species for section 7 purposes. As such, Federal agencies are only required to confer with the Service when they determine that an action they authorize fund or carry out "is likely to jeopardize the continued existence" of the species.

c) Wolves occurring outside the Central Idaho and Yellowstone nonessential experimental population areas retain their endangered status.

The Golden Sunlight Gold Mine is within the Yellowstone experimental population area. The experimental population area for the Yellowstone region includes the entire State of Wyoming, a portion of southeastern Idaho east of Interstate 15, and a portion of Montana east of Interstate 15 and south of the Missouri River. The Central Idaho experimental population area includes portions of Idaho south of Interstate 90 and west of Interstate 15. It also includes a corner of Montana south of Interstate 90, west of Highway 93 as it runs south of Missoula, south of Highway 12 to Lolo pass, and west of Interstate 15 (see attached map).

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The Service recommends that the Bureau of Land Management analyze the impacts on nonessential experimental populations, along with other populations of fish and wildlife, when complying with the requirements of the National Environmental Policy Act (NEPA) and other relevant land management statutes. Any protective measures in addition to those outlined in the final rules for managing the nonessential experimental wolf populations, or additional review procedures, are at the discretion of the Bureau of Land Management.

In accordance with section 7(c) of the Act, the Service has determined that the following listed, proposed, and category 1 candidate species may be present in or near the project area:

Listed Species	Expected Occurrence
Bald eagle (Haliaeetus leucocephalus): threatened	Winter roosting, spring/fall migrant, nesting
Gray wolf (Canis lupus): experimental	Transient
Grizzly bear (Ursus arctos horribilis): threatened	Transient
Peregrine falcon (Falco peregrinus): endangered	Spring/fall migrant
Ute ladies'-tresses (Spiranthes diluvialis): threatened	Resident in riparian, spring, and lakeside wetland meadows

Proposed Species

none

Category 1 Candidate Species	
Bull trout (Salvelinus confluentus)	Possible resident in drainages west of the Continental Divide
Mountain plover (Charadrius montanus)	Possible occurrence in shortgrass prairie habitat

Section 7(c) of the Act requires that Federal agencies proposing major construction activities complete a biological assessment to determine the effects of the proposed actions on listed and proposed species and use the biological assessment to determine whether formal consultation is required. A major construction activity is defined as "a construction project (or other undertaking having similar physical impacts) which is a major Federal action significantly affecting the quality of the human environment as referred to in the National Environmental Policy Act" (50 CFR Part 402). If a biological assessment is not required (i.e., all other actions), the Federal agency is still required to review their proposed activities to determine whether listed species may be affected. If such a determination is made, formal consultation with the Fish and Wildlife Service (Service) is required.

For those actions wherein a biological assessment is required, the assessment should be completed within 180 days of initiation. This timeframe can be extended by mutual agreement between the Federal agency or its designated non-Federal representative and the Service. If the assessment is not initiated within 90 days, this list of threatened and endangered species should be verified with the Service prior to initiation of the assessment. The biological assessment may be undertaken as part of the Federal agency's compliance of section 102 of the National Environmental Policy Act (NEPA) and incorporated into the NEPA document. We recommend that biological assessments include the following:

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1. A description of the project.
2. A description of the specific area that may be affected by the action.
3. The current status, habitat use, and behavior of T/E species in the project area.
4. Discussion of the methods used to determine the information in Item 3.
5. An analysis of the effects of the action on listed species and proposed species and their habitats, including an analysis of any cumulative effects.
6. Coordination/mitigation measures that will reduce/eliminate adverse impacts to T/E species.
7. The expected status of T/E species in the future (short and long term) during and after project completion.
8. A determination of "is likely to adversely affect" or "is not likely to adversely affect" for listed species.
9. A determination of "is likely to jeopardize" or "is not likely to jeopardize" for proposed species.
10. Citation of literature and personal contacts used in developing the assessment.

If it is determined that a proposed program or project "is likely to adversely affect" any listed species, formal consultation should be initiated with this office. If it is concluded that the project "is not likely to adversely affect" listed species, the Service should be asked to review the assessment and concur with the determination of no adverse effect.

Pursuant to section 7(a) (4) of the Act, if it is determined that any proposed species may be jeopardized, the Federal agency should initiate a conference with the Service to discuss conservation measures for those species. Although candidate species have no legal status and are accorded no protection under the Act, they are included here to alert your agency of potential proposals or listings.

A Federal agency may designate a non-Federal representative to conduct informal consultation or prepare biological assessments. However, the ultimate responsibility for section 7 compliance remains with the Federal agency and written notice should be provided to the Service upon such a designation. We recommend that Federal agencies provide their non-Federal representatives with proper guidance and oversight during preparation of biological assessments and evaluation of potential impacts to listed species. Section 7(d) of the Act requires that the Federal agency and permit/license applicant shall not make any irreversible or irretrievable commitment of resources which would preclude the formulation of reasonable and prudent alternatives until consultation on listed species is completed.

If we can be of further assistance, please contact Anne Vandehey at the address above or by phone (406) 449-5225. Your interest and cooperation in meeting our joint responsibilities under the Endangered Species Act are appreciated.

Sincerely,

Kemper M. McMaster
Field Supervisor
Montana Field Office

AMV/saw
enclosure

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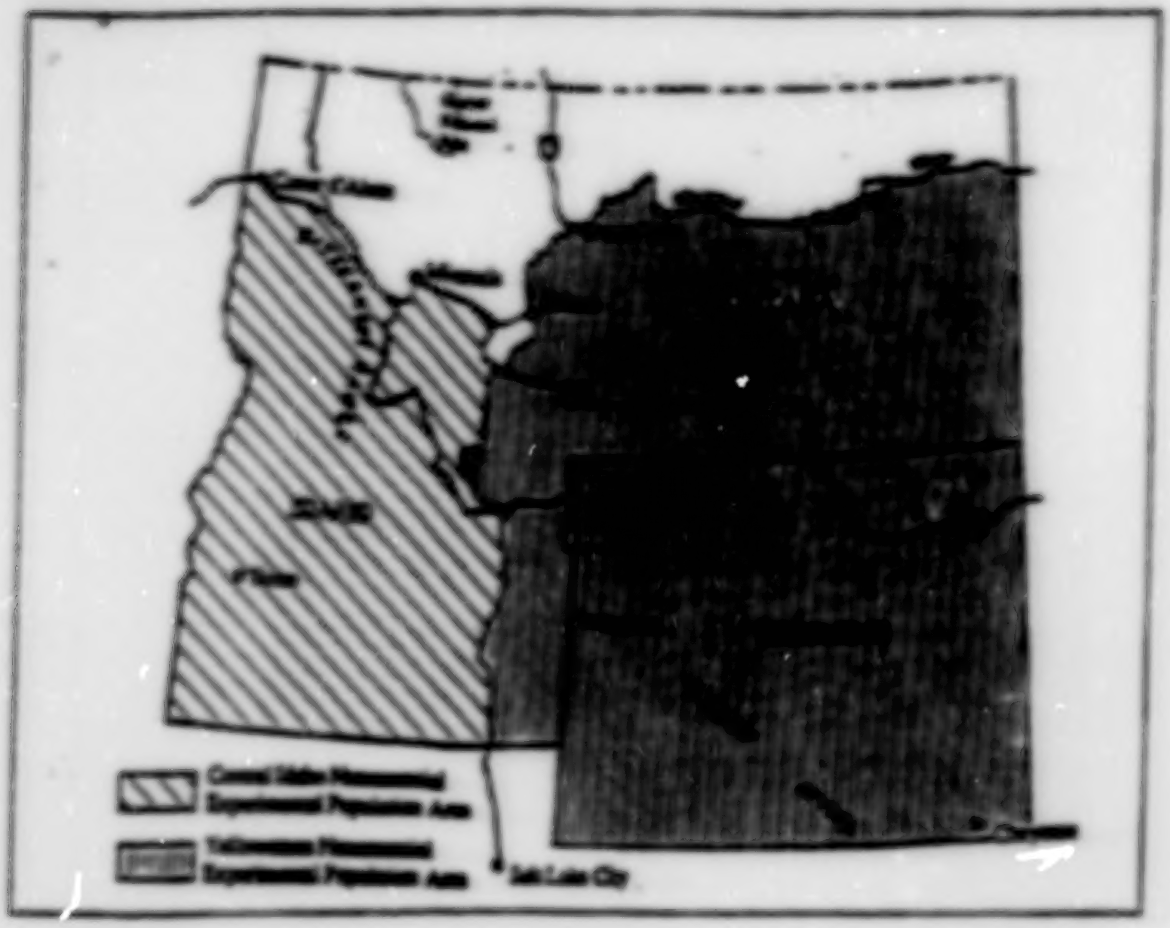
The experimental population area for the Yellowstone region includes the entire State of Wyoming, a portion of southeastern Idaho east of Interstate 15, and a portion of Montana east of Interstate 15 and south of the Missouri River. The central Idaho experimental population area includes portions of Idaho south of Interstate 90 and west of Interstate 15. It also includes a corner of Montana south of Interstate 90, east of Highway 93 as it runs south of Missoula, south of Highway 12 to Lolo Pass, and west of Interstate 15.


Boise
Salt Lake City
Cheyenne
▨ Central Idaho Nonessential Experimental Population Area
▦ Yellowstone Nonessential Experimental Population Area

Yellowstone National Park and central Idaho non-essential, experimental recovery areas.

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APPENDIX F

VISUAL RESOURCE INVENTORY AND CONTRAST RATING FORMS

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APPENDIX F

VISUAL RESOURCE INVENTORY

The Visual Resource Inventory (VRI) is a BLM management tool used to describe the relative value of the visual resources in an area, and to guide the selection of visual resource management objectives. The three elements of the VRI are scenic quality, sensitivity level, and distance zone. An assessment of these three components will lead to the rating of the area as Class I, II, III, or IV, with Class I representing areas with the most visual resource value and Class IV with the least.

For purposes of analysis, the study area was defined as the ridgeline encompassing mining activity and surrounding BLM lands - an area extending approximately four miles north from the toe of the ridge and including both east and west slopes and parts of the surrounding valley. Field reconnaissance was conducted in October 1995, and photographs were taken from several Key Observation Points (KOPs). KOPs are locations with typical views or in areas of high use, such as transportation corridors, residential areas, scenic overlooks, or recreation areas. KOPs for this analysis were points along Interstate 90 and Montana Highway 69, the towns of Whitehall and Cardwell, and recreation locations along the Jefferson River. Two KOPs, representing typical views, were used as the focus of this analysis - one along I-90 at the Whitehall exit approximately 3 miles west of the ridge; the other along Highway 69 approximately 2 miles east of the ridge.

Scenic Quality

Scenic quality is a measure of the visual appeal of a tract of land. A rating of A, B, or C is assigned depending upon the evaluation of seven key factors: landform, vegetation, water, color, adjacent scenery, scarcity, and cultural modifications. In general, lands of high scenic value (Class A) have a landscape character of high, rugged, forested mountains; tree-lined river bottoms; river gorges; or major lakes (BLM 1983). Lands of low scenic value (Class C) have a landscape character of broad, flat, or round valley bottoms or foothills and plains with few or no trees and low water features. Lands with characteristics in between A and C are rated as having moderate scenic value (Class B).

Scenic quality is evaluated in relationship to the natural landscape. Man-made features may compliment or enhance the scenic value, depending on the bias of the viewer. Harmony is an important element to this evaluation. All public lands are considered to have scenic value, but those with the most variety and harmony are rated with the highest scenic value (BLM 1980). Although no scenic quality rating has been assigned to the specific area around the Golden Sunlight Mine, the Headwaters Resource Area RMP states generally that 4 percent of the land in the Resource Area is designated as Class A, 39 percent as Class B, and 57 percent as Class C (BLM 1983).

The first component of the scenic quality evaluation is the landscape character analysis. This provides a baseline description of the visual resources of the area and can be used later on for an analysis of the visual contrast that would be created by a proposed project, development, or management activity. Four elements are described in the landscape character analysis - form, line, color, and texture. After the landscape character analysis, a rating of A, B, or C is assigned. The scenic quality evaluation of the study area was completed on BLM Form 8400-1, included at the end of this section. Table F-1 shows the landscape character description. The area scored 16 and rated Class B, with moderate scenic value.

Sensitivity Level

Sensitivity Level Analysis measures the public concern for scenic quality, rating lands with a high, medium, or low sensitivity in several categories: type of users, amount of use, public interest, adjacent land uses, special areas, and other factors (BLM 1986). BLM guidelines for sensitivity level analysis are as follows:

- **Type of Users:** Visual sensitivity will vary with the type of users. Recreational sightseers may be highly sensitive to any changes in visual quality, whereas workers who pass through the area on a regular basis may not be as sensitive to change;

- **Amount of Use:** Areas seen and used by large numbers of people are potentially more sensitive. Protection of visual values usually becomes more important as the number of viewers increases;

- **Public Interest:** The visual quality of an area may be of concern to local, state, or national groups. Indicators of this concern are usually expressed in public meetings, letters, newspaper or magazine articles, newsletters, land-use plans, etc. Public controversy created in response to proposed activities that would change the landscape character should also be considered;

- **Adjacent Land Uses:** The interrelationship with land uses in adjacent lands can affect the visual sensitivity of an area. For example, an area within the viewshed of a residential area may be very sensitive, whereas an area surrounded by commercially developed lands may not be visually sensitive;

- **Special Areas:** Special consideration must be made of management objectives for designated Natural Areas, Wilderness Areas, Scenic Areas, Wild and Scenic Rivers, etc.;

- **Other Factors:** Consider any other information such as research or studies that include indicators of visual sensitivity (BLM 1986).

The sensitivity level evaluation of the study area was completed on BLM Form 8400-6, included at the end of this section. The ratings and descriptions in each category are provided in Table F-2. The sensitivity level of the study area was rated moderate overall.

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Table F-1

Scenic Quality Analysis - Landscape Character

	Landform/Water	Vegetation	Structure
Form	Ridge with moderately steep slopes and low, rolling foothills; leveling to a broad, undulating, slightly sloping valley. Angular and terraced geometric forms created by waste rock piles, pit, and haul roads.	Diffuse, irregular, and rounded on hillsides. Irregular, rounded forms of shrubs and trees in foreground. Large, geometric bare forms created by mine disturbances.	Occasional dots of very small geometric structures in foreground and middleground. In some areas - straight horizontal strip in foreground created by frontage road.
Line	Irregular, rolling, horizontal ridge line. Diagonal and curved on slopes. Undulating, broken and horizontal to low diagonal in valley. Sharp horizontal, diagonal, and vertical in mine disturbance areas.	Some curved and diagonal broken lines in hillsides. Irregular, rolling, and horizontal lines in low foothills and valleys.	In some areas - straight, horizontal line in foreground created by frontage road.
Color	Fairly uniform, dull shades of tan. Mine disturbance creates areas of bright tan, cream, whitish-gray, and darker brown.	Dark green trees on slopes. Tan, gold, and cream grasses intermixed on slopes and in valleys. Dull orange, sage, and olive green shrubs intermixed in foreground.	Various - small spots of tan, white, gray, dark brown, and blue.
Texture	Moderately rough on slopes and foothills. Moderately smooth in valleys. Mine areas are moderately smooth.	Uneven and patchy (ranging from sparse to dense) on hillsides. Smooth in valley, with a few scattered shrubs and trees. Foreground is medium to coarse grained.	Occasional dots of structures (buildings) in valleys - very sparse.

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Form 8400-4
(September 1985)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

SENSITIVITY LEVEL RATING SHEET

Date February 1996

District Butte

Resource Area Headwaters

1. Evaluators (names)
Randa Gahin (Assistance provided by Karin Sable, Randy Rasmussen, Drew Ludwig, Jon Holst, Jon Alstad, and Brad Rixford.)

SENSITIVITY LEVEL RATING UNIT (1)	Type of Users (2)	Amount of Use (3)	Public Interest (4)	Adjacent Land Uses (5)	Special Areas (6)	Other Factors (7)	Overall Rating (8)	EXPLANATION (9)
Area was analyzed as a single unit	L/M	H	M	L/M	NA	–	M	See attached table.

Instructions on reverse

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INSTRUCTIONS

Steps in the Sensitivity Level Analysis

1. Divide the inventory area into logical sensitivity rating units.

2. Analyze the factors which indicate visual sensitivity.

3. For each rating unit, rate each factor as high, moderate, or low using the following outline as a general guide.

   a. *Type of Users:* Maintenance of visual quality is:

      — a major concern for most users .... **High**
      — a moderate concern for most users .... **Moderate**
      — a low concern for most users .... **Low**

   b. *Amount of use:* Maintenance of visual quality becomes more important as the level of use increases (see table below):

      — high level of use .... **High**
      — moderate level of use .... **Moderate**
      — low level of use .... **Low**

   c. *Public Interest:* Maintenance of visual quality is:

      — a major public issue .... **High**
      — a moderate public issue .... **Moderate**
      — a minor public issue .... **Low**

   d. *Adjacent Land Uses:* Maintenance of visual quality to sustain adjacent land use objectives is:

      — very important .... **High**
      — moderately important .... **Moderate**
      — slightly important .... **Low**

   e. *Special Area:* Maintenance of visual quality to sustain Special Area management objectives is:

      — very important .... **High**
      — moderately important .... **Moderate**
      — slightly important .... **Low**

4. **Determine the over-all sensitivity level for each rating unit. This is a judgmental process which requires a careful analysis of all the above factors. Review the ratings given to each factor and analyze the relationship between factors. A high rating in any one factor does not necessarily mean that the over-all sensitivity level rating should be high. For example, the rating for "type of users" might be high but the "amount of use" might be low. Consequently, the over-all rating could be low or moderate. Management should be involved in this rating process.**

5. **Record the ratings and explanation on the sensitivity level rating sheet.**

TABLE FOR CLASSIFYING AMOUNT OF USE

TYPE AREA	HIGH	MODERATE	LOW
Roads & Highways	Greater than 45,000 visits/yr	5,000-45,000 visits/yr	Lesser than 5,000 visits/yr
Rivers & Trails	Greater than 20,000 visits/yr	2,000-20,000 visits/yr	Lesser than 2,000 visits/yr
Recreation Sites	Greater than 10,000 visitor days/yr	2,000-10,000 visitor days/yr	Lesser than visitor 2,000 days/yr

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Table F-2

Sensitivity Level Analysis - Description of Ratings

Category	Rating	Description
Type of Users	Low / Moderate	The majority of users are local residents and travelers along I-90 and Hwy 69. Visual quality is a relatively low concern for local residents. Many work at the mine or gain a direct benefit from the mine, and are accustomed to views of the ridge and the existing visual disturbance. Travelers on the roadways have a moderate concern for visual quality. Travelers' views are transient, but the ridge is visible for several miles in either direction. Also, travelers through the western U.S. are likely to be somewhat concerned about scenic quality.
Amount of Use	High	Two major roadways, I-90 and Hwy 69, pass within 1 to 2 miles of the ridge and have views for several miles. I-90 is the major east-west thoroughfare of southern Montana. Traffic on the two roadways exceeds 2 million vehicles per year. The ridge also is within view of two small towns. Other areas of the valley are sparsely populated. Dispersed recreational use is light.
Public Interest	Moderate	Generally, visual quality is a relatively low concern for the local residents. However, some public concerns over aesthetic and recreation impacts were expressed in the public scoping of the Golden Sunlight Mine.
Adjacent Land Uses	Low / Moderate	Most land within the immediate viewshed of the project is privately owned and developed for ranching and agriculture. Visual quality is only slightly important for these land uses. Residential land uses in the area are more sensitive to visual quality. Recreation use is moderately to highly affected by visual quality, but recreation use in the area is light, most users are local residents, and views for those fishing along the Boulder and Jefferson Rivers (the largest recreation uses) are often partially obscured by riverbanks and trees.
Special Areas	Not Applicable	No designated special areas exist within the viewshed of the study area.
Other Factors	-	No other factors were considered.
Average Rating	**Moderate**	**An important factor in the overall rating of the area is its position on a prominent ridgeline, visible for several miles and within the viewshed of two major roadways.**

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Distance Zone

Distance zones delineate relative visibility from travel routes or observation points (BLM1986). The three distance categories are foreground-middleground, background, and seldom-seen. Distance zones describe the trend that the shorter the distance, the greater the visual impact. They are also related to viewer sensitivity. Foreground-middleground is defined as located within 3 to 5 miles of a travel route. Background is defined as located beyond the foreground-middleground, but within 15 miles. Seldom-seen refers to an area beyond the background or within the other zones, but not visible. For areas where the foreground-middleground zone from one travel route overlaps the background from another route, only the foreground-middleground designation is used. The distance zone for most of the study area falls within the category of foreground-middleground.

Conclusion/Results

BLM visual resource classification is determined by the following matrix:

Sensitivity Level:	**Scenic Quality:**				**Distance Zone:**
	Special Areas	**A**	**B**	**C**	
High	I	II	II	III	**fore/middleground**
	I	II	III	IV	**background**
	I	II	III/IV*	IV	**seldom seen**
Moderate	I	II	III	IV	**fore/middleground**
	I	II	IV	IV	**background**
	I	II	IV	IV	**seldom seen**
Low	I	II	IV	IV	**seldom seen**

*If adjacent area is Class III or lower, Class III is assigned; if higher, Class IV is assigned.

Class I is assigned to all special areas. Class II is assigned to all areas with Class A scenic quality. Other areas are assigned a Class II, III, or IV depending on the combination of scenic quality, visual sensitivity and distance zone. The study area has Class B scenic quality, moderate visual sensitivity and a foreground/middleground distance zone. It is, therefore, rated Class III. The management objective for Class III is to partially retain the existing character of the landscape. The level of change to the characteristic landscape should be moderate. Management activities may attract the attention but should not dominate the view of the casual observer. Changes should repeat the basic elements found in the predominant natural features of the characteristic landscape (BLM 1986).

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Form 8400-4
(September 1985)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VISUAL CONTRAST RATING WORKSHEET

Date 3-7-96 (Photo taken in Oct. 1995)

District Butte

Resource Area Headwaters

Activity (program) Mine Expansion

SECTION A. PROJECT INFORMATION

1. Project Name
Golden Sunlight Mine

2. Key Observation Point - #1
I-90 at Whitehall Exit

3. VRM Class
Class III. (Interim rating)

4. Location
Township 2 N.
Range 4 W.
Section 33

5. Location Sketch

SECTION B. CHARACTERISTIC LANDSCAPE DESCRIPTION

	1. LAND/WATER	2. VEGETATION	3. STRUCTURES
FORM	Moderately steep slopes; low rolling foothills. Angular & terraced geometric forms from current mine.	Diffuse, irregular, and rounded.	Small dots or geometric forms scattered in valley.
LINE	Rolling, horizontal ridge line; diagonal and curved on slopes. Sharp horizontal, diagonal, & vertical in mine disturbance areas.	Irregular curved and diagonal.	Horizontal line created by frontage road.
COLOR	Tan. Mine areas are bright tan, cream, white, & gray.	Dark green forest intermixed with tan and gold grasses.	Various - tan, white, gray, dark brown, blue. Gray road.
TEXTURE	Moderately rough. Mine areas are smooth.	Coarse and mottled.	Sparse. Road-smooth

SECTION C. PROPOSED ACTIVITY DESCRIPTION

	1. LAND/WATER	2. VEGETATION	3. STRUCTURES
FORM	No changes visible.	No changes visible.	No additional structures.
LINE	"	"	"
COLOR	"	"	"
TEXTURE	"	"	"

SECTION D. CONTRAST RATING ☒ SHORT TERM ☐ LONG TERM

1. DEGREE OF CONTRAST (see other side for explanation)

	FEATURES											
	LAND/WATER BODY (1)				VEGETATION (2)				STRUCTURES (3)			
ELEMENTS	Strong	Moderate	Weak	None	Strong	Moderate	Weak	None	Strong	Moderate	Weak	None
Form				X				X				X
Line				X				X				X
Color				X				X				X
Texture				X				X				X

2. Does project design meet visual resource management objectives? ☒ Yes ☐ No (Explain on reverse side)

3. Additional mitigating measures recommended ☐ Yes ☒ No (Explain on reverse side)

Evaluator's Names: Randa Gahin
Date: 3-7-96

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KOP 1

Section D. - Contrast Rating

1. Land/Water & Vegetation - No changes would be visible from this KOP. The size of the West Waste Rock Dump would not change. Other changes would not be visible.

Structures - No additional structures are proposed.

2. + 3. Because proposed activities would not be visible from this KOP, there would be no visual contrasts recorded. However, previous disturbances contrast strongly with the natural landscape and would require mitigation as "rehabilitation areas" as they do not comply with VRM Class III objectives.

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Form 8400-4
(September 1985)

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

VISUAL CONTRAST RATING WORKSHEET

Date 3-7-96 (Photo taken in Oct. 1995)

District Butte

Resource Area Headwaters

Activity (program) Mine Expansion

SECTION A. PROJECT INFORMATION

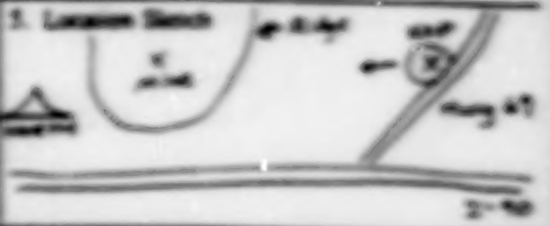
1. Project Name
Golden Sunlight Mine

2. Key Observation Point - #2
Hwy 69, east of mine

3. VRM Class
Class III (Interim rating)

4. Location
Township 2 N
Range 3 W
Section 32 or 33

5. Location Sketch



SECTION B. CHARACTERISTIC LANDSCAPE DESCRIPTION

	1. LAND/WATER	2. VEGETATION	3. STRUCTURES
FORM	Moderately steep slopes; low rolling foothills. Angular & terraced geometric forms from current mine.	Diffuse, irregular, and rounded - a few patches.	Distant dots in foothills.
LINE	Rolling horizontal ridge line; diagonal & curved on slopes; sharp horizontal, diagonal, & vertical in mine area.	Irregular, broken, curved and diagonal.	None.
COLOR	Tan and brown. Mine areas are bright tan, cream, white, and gray.	Dark green and olive green trees. Tan and gold grasses.	White and gray specks.
TEXTURE	Moderately rough; mine areas are moderately smooth.	Coarse and mottled hills. Grass areas are moderately smooth.	Very sparse.

SECTION C. PROPOSED ACTIVITY DESCRIPTION

	1. LAND/WATER	2. VEGETATION	3. STRUCTURES
FORM	Increase in size, and additions to angular, terraced geometric forms of pit & waste rock pile.	Increase in size of current bare, devegetated geometric form.	No additional structures.
LINE	Sharp horizontal, vertical, and diagonal.	Shift of current sharp diagonal & horizontal lines between [illegible] disturbed areas & vegetated natural areas.	—
COLOR	Bright tan, cream, and whitish-gray.	Increase in brightly colored devegetated areas.	—
TEXTURE	Smooth.	Increase in smooth devegetated areas.	—

SECTION D. CONTRAST RATING ☒ SHORT TERM ☐ LONG TERM

1.

DEGREE OF CONTRAST (See other side for explanation)	FEATURES											
	LAND/WATER BODY (1)				VEGETATION (2)				STRUCTURES (3)			
	STRONG	MODERATE	WEAK	NONE	STRONG	MODERATE	WEAK	NONE	STRONG	MODERATE	WEAK	NONE
ELEMENTS Form		X				X						X
ELEMENTS Line		X				X						X
ELEMENTS Color		X				X						X
ELEMENTS Texture		X				X						X

2. Does project design meet visual resource management objectives? ☒ Yes ☐ No (Explain on reverse side) (See reverse side)

3. Additional mitigating measures recommended
☒ Yes ☐ No (Explain on reverse side)
(See reverse side)

Evaluator's Names Date
Randa Gahin 3-7-96

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KOP 2

Section D. - Contrast Rating

1. Land/Water & Vegetation - Additional visual disturbances will be noticeable, but will blend with the existing disturbance. However, current and proposed disturbances have a high degree of contrast with the natural landscape.

Structures - No additional structures are proposed.

2. + 3. Additional excavations in the pit, and new portions of the east waste rock dump would be visible. The overall contrast of proposed activities is moderate in relation to existing disturbances. This rating complies with the objectives for a VRM Class III area. However, previous disturbances contrast strongly with the natural landscape, and these disturbances would be increased with the Proposed Action. Any mitigations required for these disturbances would also be required for any increases in disturbance.

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APPENDIX G

CULTURAL RESOURCE REGULATIONS

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APPENDIX G

CULTURAL RESOURCE REGULATIONS

The Antiquities Act of 1906 and the Archaeological Resources Protection Act of 1979

The Antiquities Act of 1906 was the first general act providing protection for cultural resources. It provided for protection of all historic or prehistoric ruins or monuments or any object of antiquity on federal lands, and established criminal sanctions against the injury, destruction, or unauthorized excavation of such resources. The Archaeological Resources Protection Act supplements the provisions of the Antiquities Act of 1906 in securing the protection of archaeological resources and sites on public lands. It stipulates that no person may excavate, remove, damage, or otherwise alter or deface any archaeological resource on public lands unless such activity has been permitted in accordance with the Act. The Act also calls for the notification of Native American tribes before archaeological excavation permits may be granted, particularly if an excavation or collection may have an effect on a culturally important site.

The National Historic Preservation Act

The National Historic Preservation Act established the National Register of Historic Places and the Advisory Council on Historic Preservation. In Section 106 of the National Historic Preservation Act, a five-stage process, which involved the appropriate State Historic Preservation Officer, Advisory Council, and appropriate Federal agency, was detailed to ensure that effects on historic properties are fully considered in the planning and execution of Federal projects (defined as projects involving Federal lands, funding, or licensing). Executive Order 11593 of 1971 specifically invoked the National Historic Preservation Act and directed Federal agencies to inventory their lands for cultural properties and make appropriate nominations to the National Register of Historic Places.

Consideration for listing on the Register is given to "districts, sites, buildings, structures, and objects that possess integrity of location, design, setting, materials, workmanship, feeling, and association" and that satisfy at least one of four significance criteria defined in 36 CFR part 60.4. These criteria include sites that:

(a) are associated with events that have made a significant contribution to the broad patterns of history;

(b) are associated with the lives of persons significant in our the past;

(c) embody the distinctive characteristics of a type, period, or method of construction, or that represent the work of a master, or that possess high artistic values, or that represent a significant and distinguishable entity whose components may lack individual distinction; or

(d) that have yielded, or may be likely to yield, important information in prehistory or history (Parker and King no date).

Burials are not generally eligible to the Register by definition, but are protected under other regulations.

The American Indian Religious Freedom Act

The American Indian Religious Freedom Act mandated that Federal agencies and departments protect and preserve Native American religious cultural rights and values. In practice, the American Indian Religious Freedom Act has established a set of procedures where tribal representatives are notified and asked to comment on Federal actions that may adversely affect known sites of religious or cultural value. The Archeological Resources Protection Act specifically references the American Indian Religious Freedom Act with respect to protection of culturally significant sites.

The Native American Graves Protection and Repatriation Act

The Native American Graves Protection and Repatriation Act was implemented to ensure proper and timely repatriation of Native American human remains and objects housed in museums and other institutions. The Native American Graves Protection and Repatriation Act also mandates that Federal agencies establish procedures for responding to unanticipated or new discoveries of human remains and related cultural materials on Federal and tribal lands. Graves on private land are not protected under the Native American Graves Protection and Repatriation Act; however, they are protected under the Montana Human Remains and Burial Site Protection Act.

Cultural Significance

The significance of a cultural heritage resource is an assessment of its importance to the citizens of the United States and indicates whether a site has attributes that qualify it for inclusion on the National Register of Historic Places. In order to be considered eligible for the National Register of Historic Places, a cultural resource must be a district, site, building, structure, or object that retains its integrity of location, design, setting, materials, workmanship, feeling, and association, and satisfies at least one of the four significance criteria defined in 36 Code of Federal Regulations part 60.4 (see the National Historic Preservation Act and Summary).

Cultural heritage sites also are considered significant if they are protected under other state or Federal statutes, such as the Native American Graves Protection and Repatriation Act or the Montana Human Remains and Burial Site Protection Act, which outlines procedures regarding treatment of human burials on state or privately-owned land in Montana.

An undertaking has an effect on a cultural property if it alters any of the characteristics or criteria that may qualify the property for inclusion on the National Register of Historic Places or otherwise affects a property's legally protected status. Impacts to cultural heritage resources are considered adverse if the effect diminishes the integrity of the property's location, design, setting, materials, workmanship, feeling, or association. Adverse effects can include, but are not limited to:

- Direct physical disturbance, damage, or alteration of all or part of a site or property that is listed on or is eligible for the National Register of Historic Places, or is protected under state and/or other Federal statutes;
- Isolation of the property from or alteration of the character of the property's setting;
- Introduction of visual, audible, or atmospheric elements that are out of character with the property or alter its setting;
- Neglect of a property resulting in its deterioration or destruction; and
- Transfer, lease, or sale of the property (CFR 36, 800.9, revised as of July 1, 1994).

Effects of an undertaking that have been found to be adverse as described above may be considered not adverse when:

- The property is of value only for its potential contribution to archeological, historical, or architectural research, and when that value can be preserved through appropriate research conducted in accordance with applicable professional standards and guidelines. This applies only to those sites identified as eligible to the Register under Criterion "D" and mitigated under treatment plans approved by the applicable agencies.
- The undertaking is limited to rehabilitation of structures that preserves the historical and architectural value to the property, and when transfer, sale, or lease includes restrictions or conditions that ensure the preservation of the property's significant features (36 CFR 800.9 (c)(1-3).

Sites eligible to the Register under Criteria A, B, and C that may experience adverse effects from the undertaking can sometimes be mitigated through such methods as development of educational centers or kiosks that provide information on the affected properties. Mitigation for sites nominated under Criteria A, B, and/or C that would experience adverse effects must be developed and defined in a treatment plan approved by the appropriate agencies.

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APPENDIX K

GROUND MOVEMENT FAILURE MODES AND EFFECTS ANALYSIS

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APPENDIX H

GROUND MOVEMENT FAILURE MODES AND EFFECTS ANALYSIS

General Description of Ground Movement FMEA

Potentially adverse environmental consequences are linked to ground movement potential using a Failure Modes and Effects Analysis (FMEA). Risks to the environment are evaluated by categorizing both the likelihood for ground movement to occur (failure mode likelihood categories), and the environmental impacts (consequences categories). Tables H-1 and H-2 summarize these respective categories. (Note: all tables are presented at the end of the text in this Appendix).

A level of confidence is assigned to each category of likelihood and environmental consequences. The definitions of likelihood categories are provided on Table H-3.

FMEA are categorized according to nine different modes of ground movement. These ground movements are identified by two-letter symbols, defined as follows:

BS = Movement of Sunlight or Rattlesnake Block Slips
ED = Slope Failure on East Waste Rock Dump
WD = Slope Failure on West Waste Rock Dump
BB = Slope Failure on Block Buttresses
TC = Settlement of Tailings Impoundment Covers
TD = Tailings Dam Slope Failure
PW = Pit Wall Instability
EB = Movement of East-Dump-Triggered Block Slip
DD = Slope Failure on Alternative Dump Areas

Separate FMEA tables were prepared for each primary mode of ground movement. Some tables are applicable to more than one Alternative. Table H-4 provides a comprehensive list of the ground movement FMEA tables, and indicates all the alternatives to which each table applies. The ground movement FMEA is shown on Tables H-5 through H-15.

A specific failure mode is identified by a number following the two-letter ground movement symbol on Tables H-5 through H-15. The numbered symbols identify specific modes failure that are associated with the ground movement. A brief description of each specific failure mode is provided on the FMEA tables.

The likelihood of occurrence for each failure mode is categorized and assigned a level of confidence. A likelihood/confidence level also is assigned to each primary mode of ground movement. The likelihood/confidence level assignments for individual failure modes represent the overall evaluation for that failure mode, which already incorporate the likelihood for the the principle ground movement occuring. These likelihoods should not be interpreted as being additive or cumulative.

The results of the FMEA for each Alternative are summarized and compared in the following paragraphs.

No Action Alternative

The results of the FMEA for the No Action Alternative are summarized on Table H-16. These analyses indicate that most of the identified modes of failure have a low to very low probability of occurring.

Moderately likely failure modes are primarily associated with potential block slip movements. The only failure modes that have a significant probability of occurring are related to instability (ravelling) of the pit walls and consolidation settlements on the tailing impoundment covers. These potential ground movments are anticipated to have negligible environmental consequences. The failure modes that have the most severe environmental consequences are tailings dam failures, which have very remote likelihoods of occurring.

Proposed Action

Environmental consequences and likelihood categories that are related to ground movements under the Proposed Action are essentially unchanged from those described for the No Action Alternative for the following primary failure modes:

- Movement of the Sunlight or Rattlesnake Block Slips (Table H-5): The static factor of safety is improved from 1.2 to 1.3, but this does not substantially alter the environmental risks. Consequences associated with seismically induced movement of the Sunlight Block would be mitigated because the presence of the proposed buttress would reduce the magnitude of potential block displacement. Seismic analyses indicate that with the proposed buttress emplaced, the expected maximum movement at the margins of the Sunlight Block would be up to 4 feet, compared with up to 6 feet of localized movement with only the interim buttress. This restricted movement would mitigate the consequences associated with movement of the Sunlight Block, but not enough to change the level of environmental consequences or reduce the likelihood categories as shown on Table H-5.

- Slope Failure on West Waste Rock Dump (Table H-7): Same as for the No Action Alternative.

- Slope Failure on Block Buttresses (Table H-8): The environmental consequences and failure mode likelihood categories for the enlarged proposed buttress are the same as for the interim buttress.

- Settlement of the Tailings Impoundment Covers (Table H-9): Conditions related to settlement of the reclamation cover for Tailings Impoundment No. 1 would be unchanged from the No Action Alternative. Because more tailings would be impounded in the Tailings Impoundment No. 2 facility under the Proposed Action, larger settlements may be expected compared to the No Action Alternative, but likelihood and environmental consequence level categories would not be changed from those shown on Table H-9.

- Failure of the Tailings Impoundment Dams (Table H-10): Although a larger volume of tailings materials would be involved in the failure scenarios, the consequence levels and likelihood categories are the same as for the No Action Alternative.

- Pit Wall Instability (Table H-11): Pit walls following mine reclamation would be left generally as shown in the Proposed Amendment. As for the No Action Alternative, it would be expected that some portions of the pit walls would be subject to raveling, talus formation, erosion, and limited rock mass movements, thus locally altering the configurations of some of the pit walls. In particular, rock mass movements may be expected along the northwest area of the pit, where the unfavorable orientation of existing faults renders this area less stable. As these mass movements occur, however, the overall stability of the pit walls would be expected to increase over the long-term as the rock and soil materials achieve a more stable configuration. The failure mode likelihood and environmental consequences categories would be unchanged from those presented on Table H-11.

Tables H-12 and H-13 show earth movement FMEA results that differ from the analyses developed for the No Action Alternative. The differences relate to slope stability on the expanded East Waste Rock Dump and possible East Dump-triggered block slip movements east of the Sheep Rock Creek drainage.

Table H-17 summarizes the FMEA for the Proposed Action Alternative. Entries that are different from the No Action Alternative are indicated by italics. If Table H-17 is compared with Table H-16, the only apparent difference between these alternatives relates to the potential for initiating another block slip east of Sheep Rock Creek drainage due to placement of the extended East Dump. This action has a moderate likelihood of resulting in Level II environmental consequences and a very low to negligible likelihood of resulting in Level III environmental consequences. The likelihood and consequences categories are defined on Table H-2 and Table H-3, respectively.

Return Diversion Alternative

The earth movement FMEA for the Return Diversion Alternative is identical with the analyses done for the Proposed Action, as summarized on Table H-17.

Divided Dump Alternative

Environmental consequences and likelihood categories that are related to ground movements under the Divided Dump Alternative are essentially unchanged from those described for the No Action Alternative for the following primary failure modes:

- Movement of the Sunlight Block (Table H-5);
- Slope Failure on the Interim East Waste Rock Dump (Table H-6);
- Slope Failure on the West Waste Rock Dump (Table H-7);
- Slope Failure on Block Buttresses (Table H-8);
- Settlement of the Tailings Impoundment Covers (Table H-9);
- Failure of the Tailings Impoundment Dams (Table H-10); and
- Pit Wall Instability (Table H-11).

Table H-14 shows earth movement FMEA results that differ from the analyses developed for the No Action Alternative. The differences relate to slope stability on the Alternative Dump Sites.

Table H-18 summarizes the FMEA for the Divided Dump Alternative. Entries that are different from the No Action Alternative are indicated by italics. If Table H-18 is compared with Table H-17 (Proposed Action Alternative summary), the most apparent differences are the increased number of low likelihood, Level III environmental consequences, and the slightly reduced number of moderate likelihood, Level II consequences. These differences are not substantial or significant, and appear to indicate that there is little difference in environmental risk between the Proposed Action and the Divided Dump Alternatives with respect to ground movements.

3:1 Slope Alternative

The earth movement FMEA for the 3:1 Slope Alternative is identical with the analyses done for the Proposed Action, as summarized on Table H-17. Although factors of safety would be higher for 3:1 versus 2:1 slopes, the improved waste rock dump slope stability would not substantially change the failure mode likelihood categories for the West Dump (Table H-7), the Block Buttresses (Table H-8), or the expanded East Dump (Table H-12).

No Pit Pond Alternative

Earth movement FMEA results for this alternative are identical to the Proposed Action analysis, which is summarized on Table H-17.

Partial Backfill Alternative

The earth movement FMEA results for this alternative are identical with the Proposed Action except for the Pit Wall Instability failure mode. Table H-15 shows the modified Pit Wall Instability FMEA for the Partial Backfill Alternative, and Table H-19 is the summary FMEA for this alternative. If Table H-19 and Table H-17 are compared, it is evident that there is no substantial difference in environmental risk between this alternative and the Proposed Action Alternative, with respect to potential ground movements.

Table H-1

FMEA
Likelihood Categories for Ground Movement

Category	Likelihood of Occurrence	Chance of Occurrence
Negligible	$< 10^{-6}$	<1:1,000,000
Very low	10^{-6} to 10^{-4}	1:1,000,000 to 1:10,000
Low	10^{-4} to 10^{-2}	1:10,000 to 1:100
Moderate	10^{-2} to 10^{-1}	1:100 to 1:10
Significant	Greater than 10^{-1}	Greater than 1:10

Table H-2

FMEA
Environmental Consequences Categories for Ground Movement

Category	Environmental Consequences
I	Neglible effect on water resources or the environment.
II	Failure will cause some environmental degradation in the vicinity of the mine by exposing limited volumes of ARD-generating materials, or failure will release minor quantities of metals, cyanide, or sediments to the native soil and water resources systems.
III	Failure will degrade the environment in the vicinity of the mine by exposing large volumes of ARD-generating materials or releasing major quantities of metals, cyanide, or sediments to the native soil and water resources systems. Long-term water quality and environmental degradation will occur, if action is not taken to remediate the failure.
IV	Failure will lead to major, long-term degradation of the natural environment and local water resources.

Table H-3

FMEA
Definitions for Level of Confidence

Likelihood/Consequence Confidence Category	Definition
Low	High level of uncertainty in selection of category or level; high variability possible due to lack of adequate basis for assessment.
Moderate or Medium	Some uncertainty in selection of category or level; moderate variability possible.
High	Confident estimate of category or level; adequate basis for assessment.

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Table H-4

Ground Movement FMEA
Summary of Tables for Primary Modes of Ground Movement

Table No.	Primary Ground Movement(s) Evaluated	Alternatives						
		No Action	Proposed Action	Return Diversion	Divided Dump	3:1 Slope	No Pit Pond	Partial Backfill
H-5	Sunlight or Rattlesnake Block Slips (BS)	X	X	X	X	X	X	X
H-6	(Interim) East Dump Slope Failure (ED)	X			X			
H-7	West Dump Slope Failure (WD)	X	X	X	X	X	X	X
H-8	Slope Failure on Block Buttresses (BB)	X	X	X	X	X	X	X
H-9	Settlement of Tailing Impoundment Covers (TC)	X	X	X	X	X	X	X
H-10	Failure of Tailing Impoundment Dams (TD)	X	X	X	X	X	X	X
H-11	Pit Wall Instability (PW)	X	X	X	X	X	X	
H-12	East Dump Slope Failure (ED)		X	X		X	X	X
H-13	East Dump-Triggered Block Slip (EB)		X	X		X	X	X
H-14	Slope Instability on Alternative Dump Areas (DD)				X			
H-15	(Partially Backfilled) Pit Wall Instability (PW)							X

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Table H-5

Ground Movement FMEA: No Action Alternative
Movement of Sunlight or Rattlesnake Block Slips

Symbol[1]	Stage[2]	Failure Mode	Likelihood		Environmental Effects	Consequences		Potential Compensating Factors
			Category	Confidence		Level	Confidence	
BS1	O,C	East Dump slope failure or toe disruption	moderate	high	Exposure of ARD-generating materials to surface infiltration	II	high	Regular monitoring of block movements during mine life and after closure
BS2	O,C	Disruption of Midas Spring or North Borrow Spring subdrains	moderate	high	Exposure of ARD-generating materials to buried spring flows	III	medium	GSM commits to treating seeps
BS3	O,C	Disruption of reclamation covers on Block Buttresses, and Tailings Impoundment No. 1	moderate	high	Exposure of ARD-generating, and cyanide-bearing materials to surface infiltration	II	high	Regular monitoring of block movements during mine life and after closure
BS4	O	Settlement of plant-area structures due to: (a) spreading and subsidence; or (b)collapse settlement on wetting of foundation soils	(a) moderate (b) low	high	(a) None-minor structural distress (b) Cyanide solution spills through cracks in leach tanks	(a) I (b) II	medium	(b) Water lines are installed in a concrete corridor where rupture/leaks would be quickly detected and repaired.
BS5	O	Displacement or rupture of tailing slurry and return decant water pipelines	low to moderate	high	Spills of cyanide-bearing tailing slurry or reclaim water	II	medium	Existing pipes will be replaced in 1996 or 1997 by double-lined pipes
BS6	O,C	Pit wall instability near north side of Swimming Pool Block	low	medium	Greater exposure to water of ARD-generating materials	I	high	Pit water will be treated prior to discharge to groundwater system
Summary for Movement of Block Slips:			**moderate**	**high**				

[1] BS = Movement of Sunlight or Rattlesnake Block Slips; Failure Modes 1-6.

[2] O = During operational life of mine and mill.
C = After mine closure, reclamation activities completed, and treatment facilities installed and operating.

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Table H-6

Ground Movement FMEA: No Action Alternative
Slope Failure on (Interim) East Waste Rock Dump

Symbol[1]	Stage[2]	Failure Mode	Likelihood		Environmental Effects	Consequences		Potential Compensating Factors
			Category	Confidence		Level	Confidence	
ED1	O,C	Rupture of the reclamation cover	moderate	high	Exposure of ARD-generating materials to surface infiltration	II	high	Regular inspection and repair of minor surface ruptures during mine life and after closure
ED2	O,C	Disruption of Midas Spring subdrain	moderate	high	Exposure of ARD-generating materials to buried spring flows	III	medium	GSM commits to treating seeps
ED3	O,C	Displacement of sufficient mass of waste material to partially or completely block Sheep Creek drainage	low	high	Exposure of ARD-generating materials to runoff flows in Sheep Creek drainage	III	high	Regular monitoring
Summary for Slope Failure on EWRD:			**moderate**	**high**				

[1] ED = Slope Failure on East Waste Rock Dump; Failure Modes 1-3.

[2] O = During operational life of mine and mill.
C = After mine closure, reclamation activities completed, and treatment facilities installed and operating.

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Table H-7

Ground Movement FMEA: No Action Alternative
Slope Failure on West Waste Rock Dump

Symbol[1]	Stage[2]	Failure Mode	Likelihood		Environmental Effects	Consequences		Potential Compensating Factors
			Category	Confidence		Level	Confidence	
WD1	O,C	Rupture of the reclamation cover	low	high	Exposure of ARD-generating materials to surface infiltration	II	high	Regular inspection and repair of minor surface ruptures during mine life and after closure
WD2	O,C	Disruption of Arkose Valley and/or Sunlight Spring subdrains	low	high	Exposure of ARD-generating materials to buried spring flows	III	medium	GSM commits to treating seeps
Summary for Slope Failure on WWRD:			**low**	**high**				

[1] WD = Slope Failure on West Waste Rock Dump; Failure Modes 1, 2.

[2] O = During operational life of mine and mill.
C = After mine closure, reclamation activities completed, and treatment facilities installed and operating.

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Table H-8

Ground Movement FMEA: No Action Alternative
Slope Failure on Block Buttresses

Symbol[1]	Stage[2]	Failure Mode	Likelihood		Environmental Effects	Consequences		Potential Compensating Factors
			Category	Confidence		Level	Confidence	
BB1	O,C	Rupture of the reclamation cover	low to moderate	high	Exposure of ARD-generating materials to surface infiltration	II	high	Regular inspections and repair of minor surface ruptures during mine life and after closure
BB2	O,C	Disruption of North Borrow Spring subdrain	low to moderate	high	Exposure of ARD-generating materials to buried spring flows	III	medium	GSM commits to treating seeps
BB3	O,C	Displacement of sufficient mass of buttress material to block or disrupt the storm water diversion channel south of the buttress	low	medium	Erosion and transport of sediments; exposure of ARD-generating materials to surface infiltration; ponding of runoff water on Tailings Impoundment No. 1	II	high	Regular inspections and mainenance of diversion channels during mine life and after closure
BB4	O	Disruption and damage to tailing slurry pipeline or reclaim water line where these pipelines traverse southern dump slope	low	medium	Spills of cyanide-bearing tailing slurry or reclaim water	II	medium	Existing pipes will be replaced in late 1996 to1997 by double-lined pipes
Summary for Slope Failure on Block Buttresses:			**low to moderate**	**high**				

[1] BB = Slope Failure on Block Buttresses; Failure Modes 1-4.

[2] O = During operational life of mine and mill.
C = After mine closure, reclamation activities completed, and treatment facilities installed and operating.

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Table H-9

Ground Movement FMEA: No Action Alternative
Settlement of Tailings Impoundment Covers

Symbol[1]	Stage[2]	Failure Modes	Likelihood		Environmental Effects	Consequences		Potential Compensating Factors
			Category	Confidence		Level	Confidence	
TC1	O,C	Rupture of the reclamation covers due to large differential settlements over short lateral distances	very low	medium	Increased quantity of infiltration through tailings materials, leading to increased groundwater recharge and quality degradation from Tailings Impoundment No. 1	II	high	Regular inspection and repair of surface ruptures during mine life and after closure
TC2	C	Development of surface depressions that collect storm-water and snowmelt runoff water.	significant	high		I	medium	Implementation of appropriate filling and grading plans and construction sequencing; and regular inspections and infilling of depressions
Summary for Settlement of Tailings Impoundment Covers:			significant	high				

[1] TC = Settlement of Tailings Impoundment Covers; Failure Modes 1, 2.

[2] O = During operational life of mine and mill.
C = After mine closure, reclamation activities completed, and treatment facilities installed and operating.

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Table H-10

Ground Movement FMEA: No Action Alternative
Tailings Dam Slope Failure

Symbol[1]	Stage[2]	Failure Modes	Likelihood		Environmental Effects	Consequences		Potential Compensating Factors
			Category	Confidence		Level	Confidence	
TD1	O	Static breach with water in impoundments	very low	high	Release of tailings, dissolved metals, and cyanide-bearing water to Jefferson River	IV	high	Regular monitoring of dams during mine operations
TD2	O	Earthquake breach with water in impoundments	very low	high				
TD3	C	Static breach after dewatering	very low	high	Exposure of ARD-generating materials, tailings, and cyanide-bearing materials to surface infiltration	III	high	Monitoring of dams after mine closure
TD4	C	Earthquake breach after dewatering	very low	high				
Summary for Tailings Dam Slope Failure:			**very low**	**high**				

[1] TD = Tailings Dam Slope Failure; Failure Modes 1-4.

[2] O = During operational life of mine and mill.
C = After mine closure, reclamation activities completed, and treatment facilities installed and operating.

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Table H-11

Ground Movement FMEA: No Action Alternative
Pit Wall Instability

			Likelihood			Consequences		
Symbol[1]	Stage[2]	Failure Mode	Category	Confidence	Environmental Effects	Level	Confidence	Potential Compensating Factors
PW1	C	Localized ravelling, talus formation, erosion, and limited rock mass movement	significant	high	Increased exposure of ARD-generating materials to water in pit bottom, and to precipitation runoff on pit slopes	I	high	Overall stability of pit walls will increase with time as rock and soil materials achieve more stable configurations. Pit water will be treated before being discharged to the groundwater system
PW2	C	Disruption of reclaimed benches.	moderate	medium		I	medium	
PW3	C	Disruption of pit dewatering systems by large rock falls	low	medium	Pit water rises resulting in ARD discharge to surrounding groundwater aquifers	III	medium	Regular, long-term monitoring of the water treatment systems
Summary for Pit Wall Instability:			**moderate to significant**	**high**				

[1] PW = Pit Wall Instability; Failure Modes 1-3.

[2] C = After mine closure, reclamation activities completed, and treatment facilities installed and operating.

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Table H-12

Ground Movement FMEA: Proposed Action Alternative
Slope Failure on (Expanded) East Waste Rock Dump

Symbol[1]	Stage[2]	Failure Mode	Likelihood		Environmental Effects	Consequences		Potential Compensating Factors
			Category	Confidence		Level	Confidence	
ED1	O,C	Rupture of the reclamation cover	moderate	high	Exposure of ARD-generating materials to surface infiltration	II	high	Regular inspection and repair of minor surface ruptures during mine life and after closure
ED2	O,C	Disruption of Midas Spring subdrain	moderate	high	Exposure of ARD-generating materials to buried spring flows	III	medium	GSM commits to treating seeps
ED3	O,C	Displacement of sufficient mass of waste material to partially or completely block Sheep Creek drainage	Not applicable for this Alternative. Sheep Creek drainage runoff will be diverted around the north end of the dump.					
ED4	O,C	Displacement of sufficient mass of waste material to partially or completely block Sheep Creek diversion channel	low	high	Exposure of ARD-generating materials to runoff flows in diversion channel	III	high	Regular monitoring and maintenance of diversion channel.
Summary for Slope Failure on EWRD:			moderate	high				

[1] ED = Slope Failure of East Waste Rock Dump; Failure Modes 1-4.

[2] O = During operational life of mine and mill.
C = After mine closure, reclamation activities completed, and treatment facilities installed and operating.

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Table H-13

Ground Movement FMEA: Proposed Action Alternative
Movement of East Dump-Triggered Block Slip

Symbol[1]	Stage[2]	Failure Mode	Likelihood		Environmental Effects	Consequences		Potential Compensating Factors
			Category	Confidence		Level	Confidence	
EB1	O,C	East Dump slope failure or toe disruption	moderate	high	Exposure of ARD-generating materials to surface infiltration	II	high	Regular inspection and repair of minor surface ruptures during mine life and after closure
EB2	C	Rupture of East Dump reclamation cover						
EB3	O,C	Disruption of reclamation cover and/or liner on Tailing Impoundment No. 2	negligible	high	Exposure of ARD-generating, and saturated cyanide-bearing materials to surface infiltration with possible pathway to groundwater	III	high	Favorable geology would prevent potential east side block slip movements from impacting Tailings Impoundment No. 2.
EB4	O,C	Drag-force initiates movement on Sunlight Block	very low	high	See Table H-5 for failure modes and consequences of movement of Block Slips	III[3]	medium	Potential east side block slips would not move in a direction favorable to maximizing drag forces
Summary for Movement of East Dump-Triggered Block Slip:			**moderate**	**high**				

[1] EB = Movement of East Dump-Triggered Block Slip; Failure Modes 1-4.

[2] O = During operational life of mine and mill.
C = After mine closure, reclamation activities completed, and treatment facilities installed and operating.

[3] "Worst-case" consequence level for movement of Sunlight or Rattlesnake Block Slips.

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Table H-14

Ground Movement FMEA: Divided Dump Alternative
Slope Instability on Alternative Dump Areas

Symbol[1]	Stage[2]	Failure Mode	Likelihood		Environmental Effects	Consequences		Potential Compensating Factors
			Category	Confidence		Level	Confidence	
DD1	O,C	Mass loading in Dump Area A initiates movement of the Midas Slump landslide	moderate	low	Exposure of ARD-generating materials to surface infiltration	II	high	Loaded area may be sufficiently north of landslide to avoid triggering movement - additional analyses are needed.
DD2	O,C	Mass loading in Dump Area A initiates movement of Sunlight or Rattlesnake Blocks	low	low	See Table H-5 for failure modes and consequences of movement of Sunlight Block	III[3]	medium	
DD3	O,C	Slope failure on Dump Areas B1 and B2 disrupts reclamation covers	low	medium	Exposure of ARD-generating materials to surface infiltration; impacts to drainage basins not already impacted by GSM (see Water Resources)	III	high	Infiltration seepage water quality may be mitigated by the neutralizing effects of the limestone bedrock foundation.
DD4	O,C	Slope failure on Dump Areas C1 and C2	low	medium	See Table H-7 for failure modes and consequences of Slope Failure on Interim West Dump	III[4]	medium	Regular inspection and repair of minor surface ruptures; GSM commits to treating seeps.
Summary for Slope Instability on Alternative Dump Areas:			**low**	**medium**				

[1] DD = Slope Instability on Alternative Dump Areas; Failure Modes 1-4.

[2] O = During operational life of mine and mill.
C = After mine closure, reclamation activities completed, and treatment facilities installed and operating.

[3] "Worst-case" consequence level for movement of Sunlight or Rattlesnake Block Slips.

[4] "Worst-case" consequence level for slope failure on West Dump.

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Table H-15

Ground Movement FMEA: Partial Backfill Alternative
Pit Wall Instability

Symbol[1]	Stage[2]	Failure Mode	Likelihood		Environmental Effects	Consequences		Potential Compensating Factors
			Category	Confidence		Level	Confidence	
PW1	C	Localized ravelling, talus formation, erosion, and limited rock mass movement	Not applicable for this Alternative. Pit will be partially backfilled.					
PW2	C	Disruption of reclaimed benches.						
PW3	C	Disruption of pit dewatering systems by large rock falls						
PW4	C	Localized ravelling, talus formation, erosion, and limited rock mass movement on remnant pit wall exposures	significant	high	Limited exposure of ARD-generating material to precipitation runoff; safety risks to workers.	I	high	Overall stability of pit walls will increase with time as rock and soil materials achieve more stable configurations.
Summary for Pit Wall Instability:			**moderate to significant**	**high**				

[1] PW = Pit Wall Instability; Failure Modes 1-4.

[2] C = After mine closure, reclamation activities completed, and treatment facilities installed and operating.

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Table H-16

Summary of Ground Movement FMEA
No Action Alternative

		Likelihood Category				
		Significant	Moderate	Low	Very Low	Negligible
Consequence Category	I	TC2 PW1	BS4(a) PW2	BS6		
	II		BS1 BS3 ED1	BS4(b) BS5 WD1 BB1 BB3 BB4	TC1	
	III		BS2 ED2	ED3 WD2 BB2 PW3	TD3 TD4	
	IV				TD1 TD2	

Key:

BS = Movement of Sunlight or Rattlesnake Block Slips (Table H-5).
ED = Slope Failure on East Waste Rock Dump (Table H-6).
WD = Slope Failure on West Waste Rock Dump (Table H-7).
BB = Slope Failure on Block Buttresses (Table H-8).
TC = Settlement of Tailings Impoundment Covers (Table H-9).
TD = Tailings Dam Slope Failure (Table H-10).
PW = Pit Wall Instability (Table H-11).

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Table H-17

Summary of Ground Movement FMEA
Proposed Action Alternative

		Likelihood Category				
		Significant	**Moderate**	**Low**	**Very Low**	**Negligible**
Consequence Category	**I**	TC2 PW1	BS4(a) PW2	BS6		
	II		BS1 BS3 ED1 *EB1* *EB2*	BS4(b) BS5 WD1 BB1 BB3 BB4	TC1	
	III		BS2 ED2	WD2 BB2 PW3 *ED4*	TD3 TD4 *EB4*	*EB3*
	IV				TD1 TD2	

Key:

BS = Movement of Sunlight or Rattlesnake Block Slips (Table H-5).
ED = Slope Failure on East Waste Rock Dump (Table H-12).
EB = Movement of East Dump-Triggered Block Slip (Table H-13).
WD = Slope Failure on West Waste Rock Dump (Table H-7).
BB = Slope Failure on Block Buttresses (Table H-8).
TC = Settlement of Tailings Impoundment Covers (Table H-9).
TD = Tailings Dam Slope Failure (Table H-10).
PW = Pit Wall Instability (Table H-11).

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Table H-18

Summary of Ground Movement FMEA
Divided Dump Alternative

		Likelihood Category				
		Significant	**Moderate**	**Low**	**Very Low**	**Negligible**
Consequence Category	**I**	TC2 PW1	BS4(a) PW2	BS6		
	II		BS1 BS3 ED1 *DD1*	BS4(b) BS5 WD1 BB1 BB3 BB4	TC1	
	III		BS2 ED2	ED3 WD2 BB2 PW3 *DD2* *DD3* *DD4*	TD3 TD4	
	IV				TD1 TD2	

Key:

BS = Movement of Sunlight or Rattlesnake Block Slips (Table H-5).
ED = Slope Failure on East Waste Rock Dump (Table H-12).
EB = Movement of East Dump-Triggered Block Slip (Table H-13).
WD = Slope Failure on West Waste Rock Dump (Table H-7).
BB = Slope Failure on Block Buttresses (Table H-8).
TC = Settlement of Tailings Impoundment Covers (Table H-9).
TD = Tailings Dam Slope Failure (Table H-10).
PW = Pit Wall Instability (Table H-11).
DD = Slope Instability on Alternative Dump Areas (Table H-14).

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Table H-19

Summary of Ground Movement FMEA
Partial Backfill Alternative

		Likelihood Category				
		Significant	**Moderate**	**Low**	**Very Low**	**Negligible**
Consequence Category	**I**	TC2 *PW4*	BS4(a)	BS6		
	II		BS1 BS3 ED1 EB1 EB2	BS4(b) BS5 WD1 BB1 BB3 BB4	TC1	
	III		BS2 ED2	WD2 BB2 ED4	TD3 TD4 EB4	EB3
	IV				TD1 TD2	

Key:

BS = Movement of Sunlight or Rattlesnake Block Slips (Table H-6).
ED = Slope Failure on East Waste Rock Dump (Table H-12).
EB = Movement of East Dump-Triggered Block Slip (Table H-13).
WD = Slope Failure on West Waste Rock Dump (Table H-7).
BB = Slope Failure on Block Buttresses (Table H-8).
TC = Settlement of Tailings Impoundment Covers (Table H-9).
TD = Tailings Dam Slope Failure (Table H-10).
PW = Pit Wall Instability (Table H-/5).

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APPENDIX I

ACID ROCK DRAINAGE

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APPENDIX I

ACID ROCK DRAINAGE (ARD)

ARD results from the weathering of sulfide minerals, principally pyrite (FeS_2) by water and oxygen. ARD is characterized generally as an acidic iron sulfate solution that also contains a range of trace metals (e.g., copper, zinc). The reaction that is responsible for the initiation of ARD is generally represented as:

$$FeS_2+\frac{7}{2}O_2+H_2O\rightarrow Fe^{2+}+2SO_4^{2-}+2H^+ \tag{1}$$

and proceeds rather slowly. The ferrous iron (Fe^{2+}) produced by this reaction can itself be oxidized to produce ferric iron (Fe^{3+}), which also can act as an oxidant for pyrite. This reaction is:

$$FeS_2+14Fe^{3+}+8H_2O\rightarrow 15Fe^{2+}+2SO_4^{2-}+16H^+ \tag{2}$$

Reaction 2 is generally accompanied by a marked decrease in pH and the rate of the reaction is significantly faster than reaction 1. For freshly excavated pyrite-containing waste rock, reaction 2 cannot proceed until reaction 1 is initiated. Thus, the formation of ARD is a staged process and successfully avoiding the deleterious environmental impacts associated with it must either eliminate reaction 1 or not allowing Stage II conditions (represented by reaction 2), to develop.

In conjunction with reactions 1 and 2, other geochemical reactions often accompany the formation and propagation of ARD. Excess ferric iron produced generally precipitates as an ochrous solid, producing the red-orange staining that is so characteristic of ARD. An example of this type of reaction is the formation of the solid ferrihydrite, $Fe(OH)_3$.

$$4Fe^{2+}+10H_2O+O_2\rightarrow 4Fe(OH)_3+8H^+ \tag{3}$$

It also is possible for some or all of the acidity produced to react with minerals present in associated rock matrix to either neutralize acidity (show in reaction 4 as acidity reacting with calcite, $CaCO_3$), form clay minerals (shown in reaction 5 as feldspar weathering to kaolinite) or a combination of the two.

$$CaCO_3+H^+\rightarrow Ca^{2+}+HCO_3^{1-} \tag{4}$$

$$2KAlSi_3O_8+9H_2O+2H^+\rightarrow Al_2Si_2O_5(OH)_4+2K^++4H_4SiO_4 \tag{5}$$

It can be seen that many of these reactions consume water. Thus, the formation and propagation of ARD depends on a complex interplay between sulfide minerals, availability of water and oxygen, and the chemical composition of the rock in which the pyrite occurs. Depending on the site-specific conditions, pyrite weathering reactions that lead to the formation of ARD may be suppressed, or reactions of the bulk rock matrix that occur as a result of pyrite oxidation may consume a sufficient amount of water to avoid ARD contamination of the local environment.

Minerock Types at the Golden Sunlight Mine

Rocks at the Golden Sunlight Mine are generally Precambrian in age and include sandstone, siltstone and shale. These are collectively identified as the LaHood and Newland formations and are about 1.4 billion years old. There is abundant pyrite in these materials that is a natural result of the geochemical environment in which the sediments making up the units originally accumulated. The pipe-shaped breccia in which gold mineralization also occurs contains pyrite, but this pyrite is younger than that in the LaHood and Newland formations and was probably emplaced through hydrothermal rather than sedimentary geochemical processes. However, the sedimentary (primary) and hydrothermal (secondary) pyrites can both weather agressively on exposure to water and oxygen. These pyrites are dispersed in a generally siliceous (silica based) matrix, which is for the most part geochemically inert.

Pyrite in the Golden Sunlight Mine vicinity has progressively weathered over the course of geologic time, as evidenced by the occurrence of:

- A visible rind of oxidation near ground surface compared to deeper positions exposed during excavation of the pit; and
- The presence of naturally occurring acidic iron sulfate springs on the flanks of Bull Mountain, with associated deposits of ferricrete.

Ferricrete is simply pebbles and cobbles of local country rock that have been cemented by the precipitation of ferric iron solids, like ferrihydrite (see 1). Thus, inevitably, the rocks excavated from Bull Mountain (the Golden Sunlight Mine open pit) would be expected to have a potential to form ARD.

The potential for rock excavated from the Golden Sunlight Mine to produce ARD after disposal in waste rock dumps has been previously evaluated using static and kinetic testing procedures, although little to no distinction is made between the various lithologies of the LaHood and Newland formations. Minerock is generally segregated into four groups that are unrelated to the specific geological descriptions:

- Dumped Waste Rock is unoxidized, gold-barren waste rock disposed in dumps, typically containing pyrite;
- In-Place Wall Rock is material collected from the walls of benches in the pit, to identify materials that are suitable for stockpiling for subsequent reclamation efforts on the waste rock dumps;
- In situ Oxide Cap is material that has already been used to construct caps on the waste rock dumps, as opposed to oxide rock that has been stockpiled for future use in capping; and
- Oxide Stockpile is material that has been stockpiled for future use in capping waste rock dumps.

Oxide rock is operationally defined as rock which has no visible pyrite on broken surfaces, with an external color consistent with the halo on the margins of the orebody. Confirmation on oxide rock is made using NAG testing, described below.

Geochemical Testing of GSM Minerock

Static Testing

The purpose of static testing is to determine the stoichiometric balance between acid-generating and acid-consuming components in a bulk rock sample. Approaches to this type of evaluation are acid-base accounting (ABA), net neutralizing potential (NNP), and net acid generation (NAG) testing. ABA measures the actual balance between acid potential (AP) and neutralization potential (NP) while NNP is the numerical difference between AP and NP (calculated as NP-AP). NAG testing is essentially an accelerated weathering test. Hydrogen peroxide is added to crushed waste rock samples and any generated acidity is allowed to react with acid neutralizing constituent present. The final pH is measured and used as an indicator of the

ARD potential of the solid tested. NAG testing is more rapid, less expensive, and generally equally reliable as ABA testing, if sufficient correlation of NAG results with other tests is performed.

ABA testing results are commonly interpreted in terms of the ratio of the AP and NP, both expressed as tons $CaCO_3$ equivalent/1,000 tons material. This ratio can be compared to the NNP value. The potential for a solid to generate acidity under field weathering conditions from ABA and NNP data are commonly interpreted according to the following characteristics, although there are no stringent guidelines for interpretation

Guidelines for Interpretation of ABA Results

NP/AP Ratio	NNP, t $CaCo_3$/kt	Risk for ARD
NP/AP>3		low
NP/AP<1 and/or	NNP<-20	high
NP/AP<3 and/or	NNP>-20	moderate

The static testing characteristics of each of the minerock types outlined above is summarized in Table I-1 below. Data were taken from Schafer and Associates (1994).

Table I-1

Static Testing Characteristics of Golden Sunlight Mine Minerock

Rock Type	AP t$CaCo_3$/kt	NP t$CaCo_3$kt	NP/AP	ABA t$CaCO_3$/kt	NAG pH	Risk
Dumped Waste Rock	53	4	<1	-48	3.3	high
In-Place Wall Rock	76	11	<1	-66	4.5	high
In situ Oxide Cap	13.4	10.8	<1	-2.7	5.7	moderate
Oxide Stockpile	14.9	5.4	<1	-9.5	5	moderate

The summary provided in Table I-1 indicates that none of the rock types at the Golden Sunlight Mine can be considered risk-free with respect to generation of ARD: all material has a moderate to high risk of forming ARD. In fact, all waste rock types are net acid-generators according to this method and represent a threat to the long-term environmental conditions. With a net excess of AP, the potential to produce ARD from waste rock dumps and the open pit will be largely based upon kinetic factors, which address the rate at which sulfide weathering can occur. This is dependent on water and oxygen availability and to what extent the products of that reaction can migrate.

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Kinetic Testing

Kinetic testing evaluates the rate at which minerock can weather to produce ARD, and in the case of the Golden Sunlight Mine, provides insight into which rock types are best suited for reclamation activities such as capping. As reported in Schafer and Associates (1994), kinetic testing also can be used to calibrate the results of NAG static testing with the more reliable long-term weathering behavior kinetic testing seeks to simulate. This activity helps to develop a practical tool to segregate mine waste rock types and contribute positively to proper handling of the material to avoid the formation of ARD.

Humidity cell kinetic tests are performed by continually passing humidified air through a crushed sample of solid to oxidize any sulfide minerals present, and washing the oxidation products from the cell once per week. During the test, sulfide minerals (pyrite) weather as described above to produce sulfate and acidity that can lower the rinse solution pH. During kinetic (humidity cell) testing, the rate at which sulfate is produced and pH changes is used to estimate the potential for ARD formation. The data collected during a kinetic test can range from no sulfate produced-high pH maintained, to high sulfate release rates-very low (less than 3) pH. There are no formally approved interpretation criteria to evaluate the potential of a tested material to produce ARD in field settings. Schafer and Associates (1994) offer criteria for interpretation of these tests that are widely applied at mine sites across North America and can be used as a rough guide. These criteria are not officially recognized and have not been scientifically shown to correlate to field weathering behavior. These criteria are summarized in Table I-2.

Table I-2

Estimates for Correlating Kinetic Tests Results with Potential for ARD Formation

Solution pH	Humidity Cell Response Sulfate Release Rate mg SO_4/kg_{solid}/week	Solution Acidity	Risk
Slight acid to slight alkaline	<20	none	none
Slight acid to slight alkaline	>20	low-moderate	low
Slight acid to slight alkaline	>50	low-moderate	moderate
Near 4.0 long-term	>50	moderate, increasing during test	high
Initially acidic, approach 3.0 long-term	>2000	moderate-high, increasing during test	certain

Humidity cell data have been collected for 12 waste rock samples and are reported in Schafer and Associates (1994). Nine of the samples were visibly characterized as oxide rock, one was unoxidized and two did not fit into either the oxidized or unoxidized category. A summary of the kinetic testing results for waste rock from Golden Sunlight Mine is reported below in Table I-3. It is appropriate that only one unoxidized sample was tested as this material has an average ABA of -48 and on that basis alone can be identified as very likely to produce ARD in the absence of appropriate and effective waste dump reclamation. The oxidized materials tested span a substantial range of ABA values, from -18 to +60 t $CaCO_3$/kt, with the overall average being +2. With the anomalous high value of +60 omitted, the average is -6. The average ABA for oxidized rock for all samples tested is -9.5 for the stockpile and -2.5 for the oxide cap material. The average oxidized material tested kinetically (-6) is in reasonable agreement with the average bulk character

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of oxide stock pile material (-9.5) to be used for reclamation and is thus representative. Inspection of Table I-3 shows that material with a kinetic response consistent with an ABA value of -6 is classified with a high probability of ARD formation. Thus, oxide material collected for reclamation use, with an even lower ABA, should be classified on average with the same high probability to produce ARD, though not as likely as unoxidized waste rock. Solution acidity was not presented by Schafer and Associates (1994).

Measurements of NAG pH are currently used at Golden Sunlight Mine to provide a rapid evaluation of the suitability of various oxide waste rock types for capping of dumps during reclamation activities. The NAG measurements were calibrated against the results of humidity cell measurements to determine what NAG criteria are appropriate for identifying dump cap rock. Steady-state humidity cell pH values correlate reasonably well with NAG pH´s. The NAG pH determinations are generally lower than that provided by kinetic tests, thus, it would appear to provide a conservative measure of the AP of the oxide waste rock it is used to characterize, and err on the side of environmental safety.

Table I-3

Summary of GSM Waste Rock Humidity Cell Data

	Humidity Cell Response				
Sample Character	**Solution pH**	**Sulfate Release $mgSO_4/kg_{[illegible]}/week$**	**Risk**	**NP**	**NAG pH**
Unoxidized	3.0	182.9	high	-57	2.2
Oxidized	8.5	6.8	low	-18	6.2
Oxidized	3.8	15.2	high	-7	3.6
Oxidized	3.7	26.2	high	-14	3.3
Oxidized	3.7	27.1	high	-16	3.2
Oxidized	6.9	3.6	none	2	4.9
Oxidized	6.3	12.9	low	5	5.9
Oxidized	5.7	2.8	none	1	3.9
Oxidized	6.1	3.6	none	1	4.2
N/A	7.7	10.4	none	17	6.8
N/A	8.1	9.1	none	28	6.9
Oxidized	7.9	8.5	none	60	7.0

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REFERENCES

Schafer and Associates. 1994. Draft Final Report for Golden Sunlight Mines Foundation Materials Acid Rock Drainage Attenuation Column Study, prepared for Golden Sunlight Mines, Inc., Whitehall, Montana. July 1994.

APPENDIX J

RELATIVE ARD FLUX AND NUMERICAL SIMULATION OF ARD FATE AND TRANSPORT

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APPENDIX J

1.0 BACKGROUND ARD VS. ARD FROM ACTION ALTERNATIVES

1.1 Introduction

This appendix attempts to provide a sense of the relative ARD impacts associated with each of the action alternatives. Two, independent conceptual evaluations are made. The first evaluation considers simply the production of sulfate from weathering sulfide minerals in the proximity of the mine facility. The second considers the fate and transport of any ARD that may be generated by waste rock dumps. In tandem, these two evaluations provide a sense of the range of potential geochemical behaviors that are possible at the site.

Producing an estimate for the natural, background production of ARD by Bull Mountain and comparing it to estimated flow from engineered dump facilities offers an approach to evaluating the relative importance of flow. This appendix presents a model of background and dump ARD production. The presentation consists of several parts:

- Conceptual Approach
- ARD Production Estimates
- Conclusions

The components of the system for which fluxes of ARD must be estimated include the historical weathering of Bull Mountain (ultimate background), west dump complex (on Bull Mountain with a western and eastern flank) and the eastern dump complex.

It is important to note that the following analyses are meant to provide only a general indication of the potential differences in ARD loading between background and the Proposed Action. It is very simplistic, and either ignores or lumps several complex processes together. Many of the input parameters are estimated and are not necessarily supported by actual data. Therefore, there is a large range of possible error within the model results because of the simplicity of the model and the uncertainty in model input parameters. However, the purpose of the model is not to accurately predict or quantify ARD loading. Instead, the model is intended as a general tool to approximate potential differences between EIS Alternatives.

1.2 Conceptual Approach

The rate of ARD production over the centuries by Bull Mountain will be compared to the estimated rate of ARD production by the reclaimed waste rock dumps in order to determine the incremental impact of mining operations. This rate will be calculated on the basis of sulfate loading as sulfate is a principle weathering product of sulfide mineral oxidation. The information required is the flux of water and the representative solution sulfate concentration, for both Bull Mountain and the waste rock dumps. The simple product of these quantities yields the sulfate flux and, hence, an estimate of the relative ARD generation.

The flux of water through the dumps is available from the modeling that has been completed to date. Porewater data reported in the EIS application provide a sense of the concentration of sulfate under the expected low flow conditions. Thus, estimates of the sulfate (ARD) production from the dumps can be readily accessed.

For the contributions by Bull Mountain, as a background process, estimates are more difficult, but can be made. Water flux through Bull Mountain occurs as both a lateral flow of groundwater from a northern, up gradient location toward the Jefferson Slough, or vertically as infiltration of meteoric water which moves to the groundwater table and then toward the Jefferson Slough. Because groundwater is commonly depleted and meteoric water is saturated with respect to dissolved oxygen, the infiltration of meteoric water is the principle mechanism for the weathering of sulfide minerals in Bull Mountain.

Meteoric water percolation produced the oxidized rind observed at the crest of the mountain. The natural rate of infiltration for the undisturbed mountain surface was estimated by determining the areal exposure of Bull Mountain and allowing 1.5 inches of the reported 13.3 inches/year precipitation to infiltrate (a little more than 10 percent, consistent with the hydrologic study by Hydrometrics on behalf of Golden Sunlight Mine). This flux of water is then multiplied by the average sulfate concentration in groundwater down gradient to estimate the flux of sulfate from natural weathering processes. As a check, the time required for formation of the oxidized rind can be computed from this result to be certain that something on the order of geologic time is obtained, as opposed to something on the order of a human lifetime.

1.2 ARD Production Estimates

1.2.1 *Background ARD from Bull Mountain*

The areal extent of background infiltration of meteoric water, as indicated by the bold, dashed line on the enclosed Map J-1, is defined by the topographic break in slope that is Bull Mountain. The northern bound is selected at the northern extent of the pit operation (approximately). The total area is determined by simple planimetry as 4.88 x 10^7 ft^2. The groundwater wells on the margins of Bull Mountain indicate that the sulfate concentrations are significantly lower on the western flank of the mountain than on the eastern flank (see Table J-1). Accordingly, the impact of mining operations will be different for facilities constructed on either side of the mountain relative to background conditions. Therefore, the total area for Bull Mountain considered in this analysis is further broken down to consider a western and eastern component, as indicated in Map J-1. So, the total infiltration for background weathering of Bull Mountain sulfides is the sum of the two components and is given by

Table J-1
Water Flux Through Bull Mountain Prior to Mine Development
(Ultimate Background)

Component	Western Flank	Eastern Flank
Surface Area (ft^2)	1.77 x 10^7	3.10 x 10^7
Infiltration (in/yr)	1.5 (0.125 ft/yr)	1.5 (0.125 ft/yr)
Water Flux (ft^3/yr)	2.21 x 10^6	3.88 x 10^6
Q (l/yr)	6.25 x 10^7	1.10 x 10^8
(gal/min)	31.5	55.1

The sulfate concentration required to compute the total sulfate flux per unit time is estimated from site groundwater data, which is summarized in Table J-2 below. Note the distinct difference in sulfate concentration for eastern versus western flank wells.

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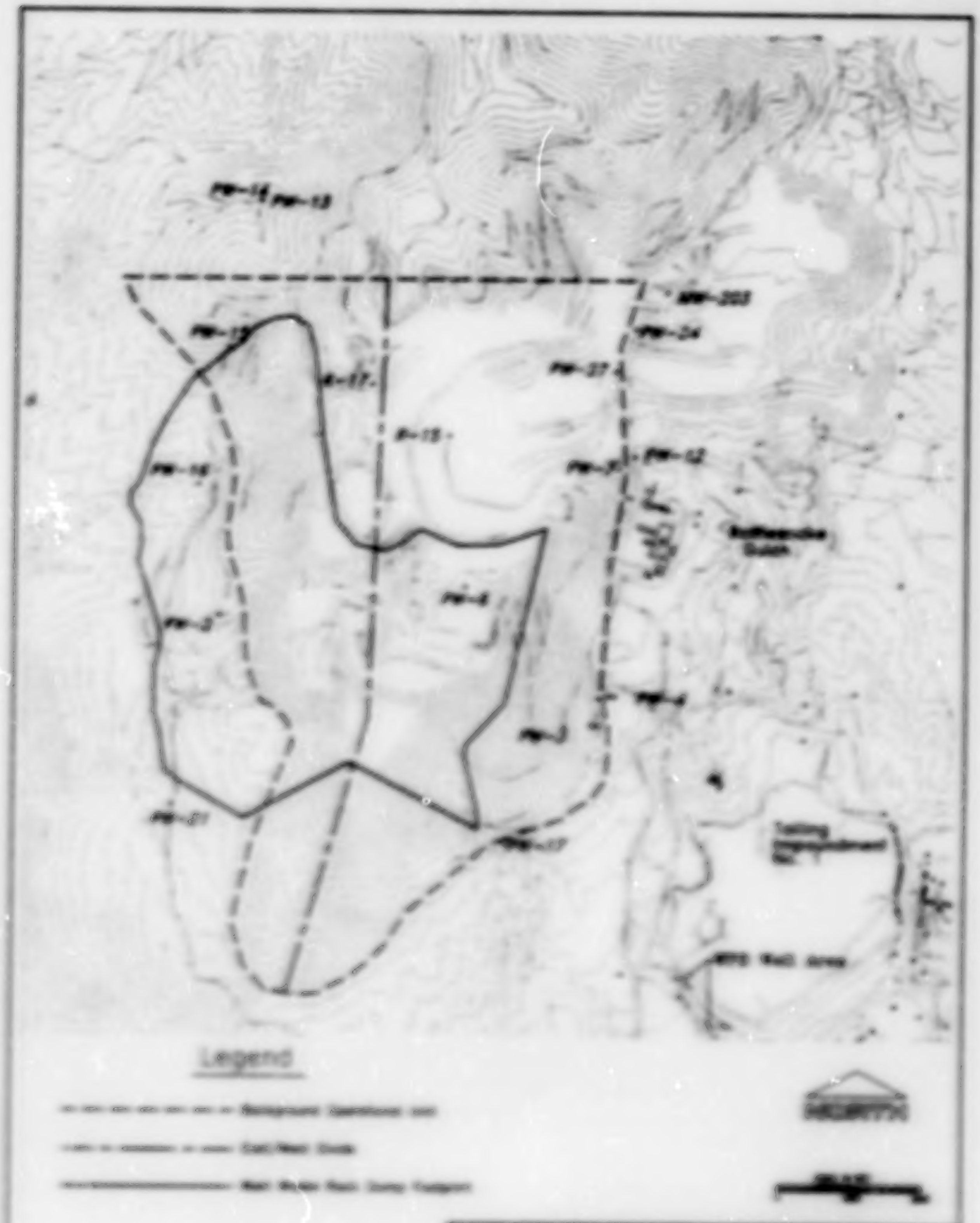

GOLDEN SUNLIGHT MINE EXPANSION

MAP J-1

BACKGROUND INFILTRATION OF METEORIC WATER

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Table J-2
Estimated Representative Sulfate Concentrations in Groundwater

Well Identification	Flank	Water Table AMSL	Screen Interval AMSL	Lithology	SO_4 mg/L
PW-2	West	5,240	5,259-5,199	argillite, sandstone	740
PW-3	East	505	5,000-4,980	latite porphry	5,160
PW-4	East	4,990	4,976-4,956	lamprophyre	4,900
PW-7	East	5,120	5,184-5,154	unavailable	4,500
PW-15	West	5,425	multiple	pyritic, carbonaceous siltite	1,240
PW-16	West	5,260	5,258-5,208	siltite	1,200
East Average					4,853
West Average					1,060

The sulfate flux for each flank can then be calculated as follows in Table J-3:

Table J-3

Sulfate Flux from Bull Mountain for Ultimate Background

Component	Western Flank	Eastern Flank
SO_4 (mg/L)	1,060	4,853
Water Flux (L/a)	6.25×10^7	1.10×10^8
SO_4 (mg/a)	6.63×10^{10}	5.33×10^{11}
SO_4 (t/a)	73	587

The calculations shown indicate that the background impact is substantially greater on the eastern flank of the mountain than on the western flank. Summing both components, there appears to be a total background impact of 660 tons per year.

1.3.2 Time to produce oxidized rind

With the estimate of the total annual sulfate loading from Bull Mountain, an estimate can be made of the time required to produce the oxidized rind observed on the margins of Bull Mountain. To make the estimate, the total mass of sulfate removed from that rind can be combined with the rate of 660 ton/yr to compute the required time.

The volume of the oxidized rind is calculated as the product of the total surface area and an estimated thickness, 4.88×10^7 ft^2 and 100 ft, respectively. Thus, the volume is calculated as 4.88×10^9 ft^3. Converting this volume to mass, a bulk rock density of 120 lb/ft^3 is assumed.

$4.88 \times 10^9\ ft^3 \times 120\ lb/ft^3 = 5.86 \times 10^{11}\ lb$

The mass of sulfide oxidized is estimated using the difference in percent sulfide sulfur in *in situ* unoxidized wall rock (2.5 percent) and *in situ* oxidized rock (0.5 percent).

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$(5.86 \times 10^{11}$ lb $\times 0.025) - (5.86 \times 10^{11}$ lb $\times 0.005) = 1.17 \times 10^{10}$ lb S
1.17×10^{10} lb S $\times$ 98 SO_4/32 S $= 3.59 \times 10^{10}$ lb $SO_4 = 1.80 \times 10^7$ tons SO_4

Lastly,
1.80×10^7 tons $SO_4 \times 1$ yr/660 tons ~27,000 years.

This value is on the order of geologic time rather than human time and thus provides some measure of confidence that the estimate of the weathering rate is of the appropriate order.

1.3.3 Waste Rock Dump ARD Estimate

The flux of water through the site following mine development will include the contribution from the dumps and from the "background" areas not covered by engineered dumps. Estimates for the infiltration of meteoric water into the waste rock dumps appear to approximate 0.25 in/yr based on HELP modeling. To assess the impact of ARD production, the ultimate background component is calculated as above except that the area of infiltration is reduced by the area that is covered by the west waste dump complex to yield the operational background. The area of overlap is shown in Map J-1 and was taken from Figure 1.5-1 of the GSM EIS application document. Overlap is not considered for the eastern dump complex, for either the No Action or Proposed Action alternative as this dump complex does not appear to significantly lap onto the competent rock of Bull Mountain, instead sitting primarily on relatively less consolidated, recent alluvial materials of the Bozeman group. The area of dump overlap onto Bull Mountain is approximately 1.63×10^7 ft², which will be partitioned into two portions, that on the eastern and western flanks of the mountain. The discussion below will outline and quantify the impacts from ARD for the No Action and Proposed Action alternatives.

The sulfate concentration required to compute the total flux is taken from observed concentrations of sulfate in reclaimed dump porewater at the leading edge of the wetting front. Table 4.2 on page 4-33 of the EIS application Appendix 5.5-1 reports data for Site 1, a reclaimed dump bench. At the 10-foot depth position, the leading edge of the wetting front, the concentration of sulfate is reported as 37,500 mg/L. The concentration of sulfate at the 40-foot depth position of Site 2, a reclaimed dump top is reported as 26,300 mg/L. A simple average of these values is 31,900 mg/L and for simplicity, the present evaluation uses a concentration of 30,000 mg/L. It is interesting and worth noting that the concentration of sulfate in porewater of the unreclaimed dump is about 210,000 mg/L at the 10-foot depth position of Site 6. With the estimated sulfate concentration in solutions that are in the dump presently, the flux of sulfate (ARD) can be estimated. The result is tabulated in Table J-4.

Table J-4

Calculation of Sulfate Flux from West and East Dump Complexes with Background Contributions from Bull Mountain not Covered by Waste Rock

Component	Operational Background		West Dump Complex		East Dump Complex	
	West Flank	East Flank	West Flank	East Flank	No Action	Proposed Action
Surface Area (acres)	161	553	390	158	482	814
Infiltration (in/yr)	1.5	1.5	0.25	0.25	0.25	0.25
Water Flux (gpm)	12.5	42.9	5.0	2.0	6.2	10.5
SO_4 (mg/L)	1,060	4,853	30,000	30,000	30,000	30,000
SO_4 (t/yr)	30	464	337	137	416	703

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Thus, the sulfate flux for the No Action Alternative is calculated as the sum of the current background, the west dump complex and the No Action surface area of the east dump complex and is equal to 1,384 t SO_4/yr. The result is a No Action alternative reduction of 724 t SO_4/yr relative to ultimate background (1,384 t/yr - 660 t/a original background from Table J-3). By way of an analogous calculation, the sulfate flux for the Proposed Action Alternative can be calculated as 1,654 t/yr. This value represents a net impact of 1,011 t/a over ultimate background. The Proposed Action Alternative produces 287 t/yr over that occurring as a result of the No Action Alternative, a 21 percent increase.

1.4 Conclusions

The results of the present modeling exercise suggests that the bulk of ARD production at the GSM facility is associated with the construction of the west dump complex's western flank. From Table J-4, the production on the western flank of Bull Mountain from mining to date (No Action Alternative) is 337 t/yr, compared to an estimated 73 t/yr for ultimate background. This represents a 5 fold, or 400 percent, increase in ARD production. The expansion of the east dump complex under the Proposed Action represents a 287 t/yr production compared to the No Action Alternative, a 21 percent increase in impact over No Action. Thus, the Proposed Action produces a relatively small incremental increase over that experienced by previously permitted activities.

2.0 FATE AND TRANSPORT OF ARD

Any precipitation infiltrating the waste rock dumps can lead to the formation of ARD in quantities consistent with the evaluation presented in Section 1 of this Appendix. The extent to which any ARD that is formed can be accessible to any user is dependant upon numerous factors, including:

- Time for percolation through the waste dump fills;
- Time for percolation through the unsaturated sediments (vadose zone) underlying the dumps;
- Time for movement of groundwater down gradient to a point of reception;
- The extent to which natural recharge in the system can offset introduced ARD by dilution; and
- The extent to which naturally-occurring minerals in the vadose zone can neutralize acidity and arrest the migration of solutions components (e.g., dissolved sulfate and metals).

This section describes a simple linear mixing cell model which was developed by the EIS preparers to predict "order of magnitude" ARD impacts to groundwater and surface water resources, and the general time frame for their occurrence. Like any numerical simulation that is used to model a complex system, the mixing cell model has inherent constraints and limitations. The model utilizes consistent logic to establish flow system geometry, natural acid-neutralizing capacity of the foundation soils, infiltration scenarios, and ARD strength. Thus it compares gross mass balance issues associated with each alternative, and the relative degree of environmental impact or protection offered by each alternative. However, quantitative model predictions of ARD concentrations at specific times and locations are considered very approximate.

The primary utility of the mixing cell simulation model is as a tool for comparing action alternatives. The model is used to compare potential impacts for a range of waste dump infiltration cases. Best, worst, and expected cases were considered, corresponding to least, greatest, and expected infiltration rates.

2.1 Mixing Cell Model Description

Figure J-1 shows a schematic representation of the mixing cell model. The model can be envisioned as a pipe, filled with the porous solid materials comprising the aquifer. The model simulates groundwater flow through the rock- and soil-filled pipe. This flow is recharged by infiltration that seeps through the waste rock fills and the unsaturated (vadose) zone overlying the aquifer.

The pipe is conceptually broken up into a number of segments, or cells, of equal length. Hypothetical ARD from waste rock dumps is introduced into the flow path at the appropriate cell. For a series of time steps, ARD from waste rock is mixed with the groundwater. Neutralization of acidity by calcite in the mixing cells occurs. Solutions pass from one mixing cell to another, progressing down the hydraulic gradient until they reach the end of the pipe.

The following assumptions are implicit in the numerical mixing cell model with regard to the interaction of the groundwater flow system and hypothetical ARD from waste rock dumps at the Golden Sunlight Mine:

1. The flow pipe has a fixed width, which is different for each action alternative.
2. The width of the flow pipe is fixed to correspond to the anticipated width of the waste rock dump associated with each alternative.

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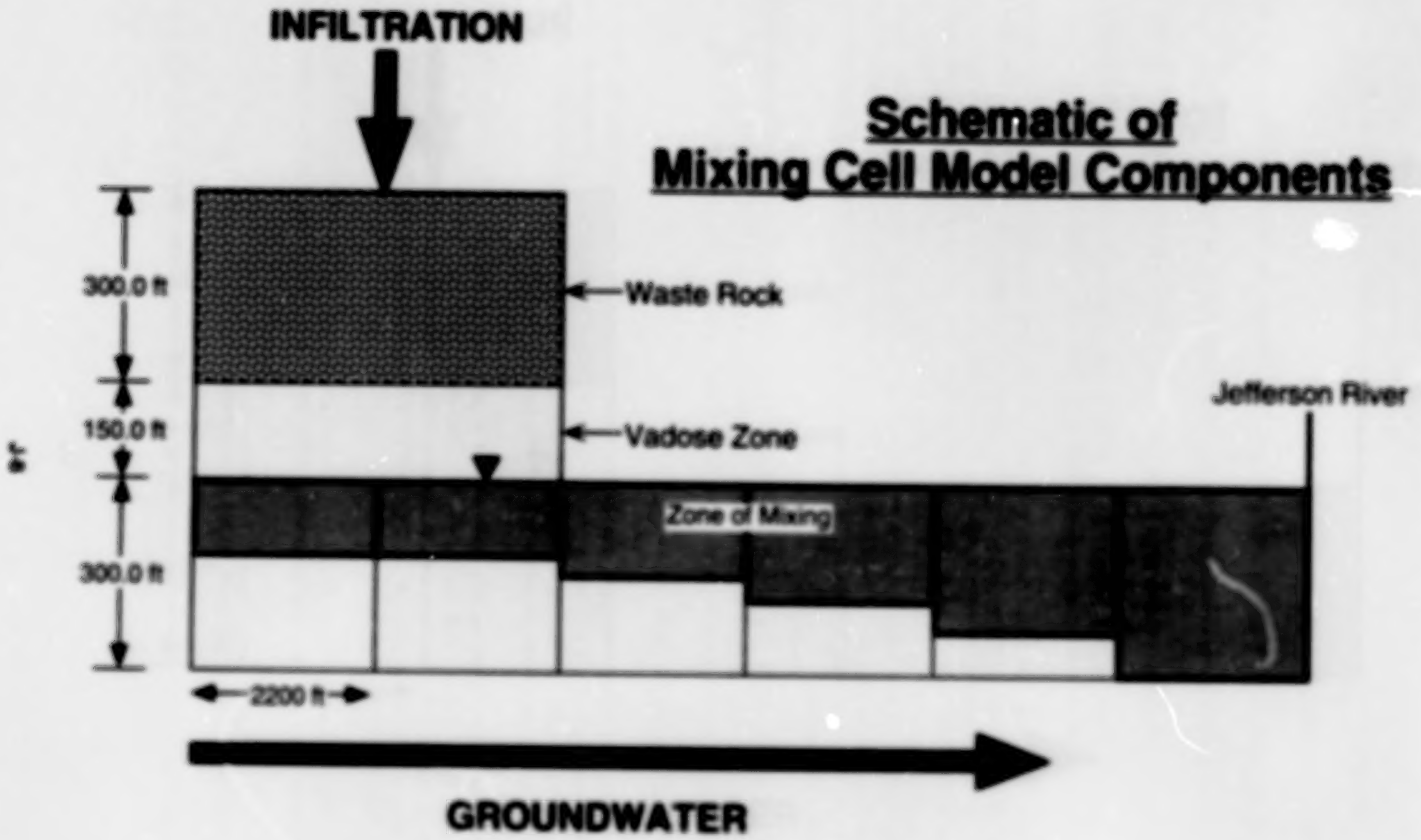

Schematic of Mixing Cell Model Components

Note: Horizontal scale not equal to vertical scale

FIGURE J-1

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3. The depth of the flow pipe gradually becomes deeper with increasing distance from the point at which hypothetical ARD is introduced to simulate the effects of dispersion in the system. Thus, in three dimensions, the flow pipe can be viewed as a wedge that is thinnest at the head.

4. Recharge groundwater is introduced at a fixed rate of infiltration along the length of the flow pipe. The recharge area is as wide as the pipe, and extends up gradient to the top of Bull Mountain, corresponding to the groundwater divide.

5. The acidity of ARD produced by the waste rock dump in the simulation is proportional to the sulfate concentration.

6. The amount of water leaving a cell during any one time step is equal to the water entering the cell at the same time step.

The numeric simulation performed in each cell can be simply described. For a given time step:

- All the water entering the cell from all sources (i.e., up gradient recharge and ARD from above) is calculated;
- Water entering the cell is thoroughly mixed with water already present in the cell;
- A portion of calcite (calcium carbonate) is consumed that is equivalent to the amount of sulfate in the cell;
- If there is a net positive amount of calcite in the cell, an upper limit of sulfate concentration is imposed of 1,600 mg/L, equivalent to equilibrium with gypsum ($CaSO_4 2H_2O$), which will form when ARD is neutralized with calcite;
- If the calcite content of a cell is consumed, no further neutralization of acidity occurs and sulfate concentrations are allowed to freely increase above 1,600 mg/L; and
- Finally, water is passed from the cell in an amount equal to what entered the cell.

Within the general framework of the mixing cell model, a number of site-specific assumptions are made. These assumptions are selected to be representative of conditions presently observed at the Golden Sunlight Mine. These assumptions are:

1. The vertical dimension of the flow pipe increases from 100 feet thick under the waste rock dumps to 300 feet thick proximal to the Jefferson River (based on independent models of dispersion).

2. The calcite content of the alluvial aquifer material on the east side of Bull Mountain is 5 percent (based on several soil/sediment surveys and literature citations of worldwide calcite contents of similar material) and is 0 percent on the west side of the mountain.

3. The hypothetical ARD leaving the waste rock dump has a sulfate content of 30,000 mg/L (based on present measurements within reclaimed dumps).

4. The total flow path length on the east side of Bull Mountain is 13,200 feet, and on the west side it is 11,000 feet.

5. The widths associated with each alternative on the east side are:

   - No Action: 2,500 feet
   - Proposed Action: 4,000 feet
   - Divided Dump Alternative: 6,000 feet

6. The widths associated with each alternative on the west side are

   - No Action: 9,000 feet
   - Proposed Action: 9,000 feet
   - Divided Dump Alternative: 11,000 feet.

7. Groundwater recharge is limited to 0.8 inch/year under the West Waste Rock Dump to account for runoff over the shallow bedrock surface. Up to 2 inches per year (worst case infiltration) is allowed to infiltrate the Bozeman Formation vadose zone underlying the East Waste Rock Dump.

8. The time required for net infiltration on dump surfaces to travel through the waste rock and underlying vadose zone before reaching the groundwater was estimated based on a variety of independent models and is presented in Section 2.2.

9. ARD production from waste rock dumps has a limited lifetime, which is shorter for greater rates of precipitation infiltration into the dumps, and longer for very low infiltration rates; ARD production stops at some point in the mixing cell simulation.

Numerically, the concentration of sulfate in each cell is tracked over time and the results are graphed. Graphical output from the model shows the model's calculated sulfate concentration within each cell as a function of time, and extends for a period of time exceeding the projected duration of ARD production.

Estimation of metal concentrations associated with transport of ARD is a complex task, as it is complicated by a number of geochemical processes such as adsorption which are not easily quantified. For the present evaluation, however, data from ARD attenuation column studies performed by Shafer and Associates (1994) are used to establish rough correlations between sulfate concentration and concentration of arsenic (As), cadmium (Cd), copper (Cu), manganese (Mn), and zinc (Zn). The correlations obtained from the column study data are used for the east side only, because the column tests simulate interaction with alluvial materials in that area of the site.

For the west side, ARD interaction with alluvial material is not anticipated to occur to any significant extent. Metal concentrations are estimated on the west side by assuming a simple dilution of ARD with groundwater having appropriate background chemistry based on existing water quality data from the site. The dilution analysis for the west side is cast in terms of correlating sulfate concentration with metal concentrations, similar to the approach used for the east side.

In summary, the mixing cell model provides an estimate of sulfate concentration as a function of both time and proximity to the dumps. The east and west sides of the mine site were evaluated separately because of the distinctly different geologic and aquifer conditions in those areas. The No Action, Proposed Action, and Divided Dump Alternatives were modeled for sulfate. Metal concentrations were then estimated in a gross manner by correlating predicted sulfate concentrations with concentrations of various metals. The sulfate-metal correlation relationships for the east side were established from limited column test data representing the geochemical behavior in the alluvial materials. For the west side, metals concentrations also are correlated with sulfate concentrations, but the attenuation is attributed to dilution only, and not to interaction with alluvium.

2.2 Time of Travel Through Dumps and Vadose Zone

2.2.1 Approach

The time required for infiltrating water to migrate through the waste rock dumps and the underlying unsaturated soils down to the water table is dependent on the initial water contents, the long-term (steady state) water contents, and the unsaturated hydraulic conductivities of the dump fill and foundation materials. In these analyses, water content, θ, is expressed as a ratio of the volume of water, V_w, in a representative unit volume of the porous material, V: $\theta = V_w/V$. The dump materials typically are placed in a very dry condition. Net infiltration of precipitation through the reclamation covers will

cause the volumetric water content (θ) within the dumps and the underlying foundation vadose zone to increase gradually with time.

Unsaturated hydraulic conductivity, K_w, is a measure of the ease with which water is transmitted through the unsaturated soil and rock fill materials. The magnitude of K_w depends on both the volumetric water content, and the distribution of pore sizes within each material. K_w therefore varies in both time and space.

The time-of-travel is predicted by considering, independently, the processes of 1) initial wetting of the unsaturated waste rock/soil profile, followed by 2) steady downward seepage. The process in which the waste rock/soil material is being initially wetted was evaluated by University of Saskatchewan researchers (Wilson 1996a). It was assumed that the initial volumetric water content in the dumps (θ_i) is lower than the level at which soil moisture movement can begin, and that water must be added to bring the soil moisture up to that level. The model assumption is that vertical seepage will not commence until the soil moisture exceeds a residual volumetric water content referred to as the specific retention (θ_r). The amount of time required to reach this moisture condition is estimated by

$$t_w = \frac{(\theta_r - \theta_i)}{I}\,h \qquad (1)$$

where:
t_w = time to wet to θ_r
θ_i = initial volumetric water content ($<\theta_r$)
θ_r = residual volumetric water content (also known as specific retention, irreducible water content, or minimum water content)
I = infiltration rate
h = height of the waste rock dump

The steady-state time of travel applies after the soil/rock fill material has exceeded this moisture level. The steady-state time of travel can be calculated using the following equation for seepage velocity (Stephens 1996)

$$v = \frac{q}{\theta_e} = \frac{I}{\theta - \theta_r} \qquad (2)$$

where:
v = seepage velocity
q = flow rate (flux)
θ_e = effective volumetric water content
θ = volumetric water content of the soil during seepage ($>\theta_r$)

In summary, the total travel time predicted by this simple model depends on the following variables: 1) the initial volumetric water content (θ_i) and 2) residual volumetric water content (θ_r) of the soil/rock fill materials; and 3) the net infiltration rate (I).

2.2.2 Model Input Parameters

Infiltration Rate

The net infiltration rate (I) for reclaimed waste dumps is estimated to be between 0.25 and 0.5 inch per year. Net infiltration for unreclaimed dump surfaces is assumed to be up to 2 inches per year.

Initial Soil Moisture

Wilson (1996a) estimates the average initial volumetric water content over the full depth of the waste rock profile to be approximately 3.6 percent. This value is not supported by field data for the waste rock dumps. Neutron probe moisture profiles presented on Figures 2-2 through 2-17 of the 1995 GSM Annual Report (GSM 1996) show variable moisture in the dumps with minimum values of about 5 percent. An initial moisture of 5 percent was assumed for the time to wet calculations.

Residual Soil Moisture

Residual volumetric water content, θ_r, is a concept that has a number of different physical interpretations. It is usually defined as the water content at which significant increases in capillary pressure (soil suction) produce negligible decreases in water content. Residual water content is often associated with the "drainable" porosity. The magnitude of θ_r depends in part on the grain size, sorting, and pore space size of the material. The pore space that still contains water at water contents less than residual (i.e., at $\theta < \theta_r$) contributes very little to processes of convective flow (Corey 1977).

Another parameter that is reported in some of the technical documents at GSM is the "field capacity". The field capacity is a concept that is somewhat related to the residual water content. The term usually refers to the water content of a column of soil after it has been thoroughly wetted, then allowed to drain from the bottom while being protected from evaporation. Some soil scientists consider the field capacity to correspond with the volumetric water content at 1/3 bar (33kPa) suction, on a drainage curve.

The average value of the residual volumetric water content θ_r is important in the time-of-travel calculations, because it is assumed that flow will not begin until the dump material water content has exceeded this level. The residual volumetric water content has been estimated for the waste dump materials by several different methods. These methods and results are summarized below:

Estimates of θ_r Based on Soil Moisture Characteristic Curves - University of Saskatchewan. The University of Saskatchewan collected numerous soil samples from the waste rock dumps, as part of thesis research conducted by Greg Herasymuik (Herasymuik 1996). Five of those samples underwent laboratory tests to determine: grain size distributions, saturated hydraulic conductivity, and soil moisture characteristic curves using a pressure plate apparatus.

Herasymiuk (1996) presented graphs showing 1) water content vs. suction head, 2) water content vs. unsaturated hydraulic conductivity, and 3) grain size distribution (Wilson 1996c). Select data were extrapolated from graphs in the thesis for use in the modeling evaluations.

The moisture characteristics for five samples are provided in Figure J-2. The fine-grained sample TP7GR3 was selected by the University of Saskatchewan for the evaluation of wetting requirements for the dumps. No information was provided for the location of that sample.

Finer-grained materials exist at the tops of the benches, according to Schafer and Associates (1995). Several documents, including the July 19, 1995, Summary of the Reclamation Monitoring Program, state that the upper 6 to 10 feet of the rock pile benches are compacted by vehicle traffic. The fines generated can result in "field capacity levels approaching 15 to 20 percent". Rock size gradually increases with depth due to gravity sorting from end-dumping, such that "field capacity decreases with depth" and "varies from 8 to 12 percent within the rock pile."

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GSM WASTE ROCK DUMP SOIL MOISTURE RETENTION CURVES

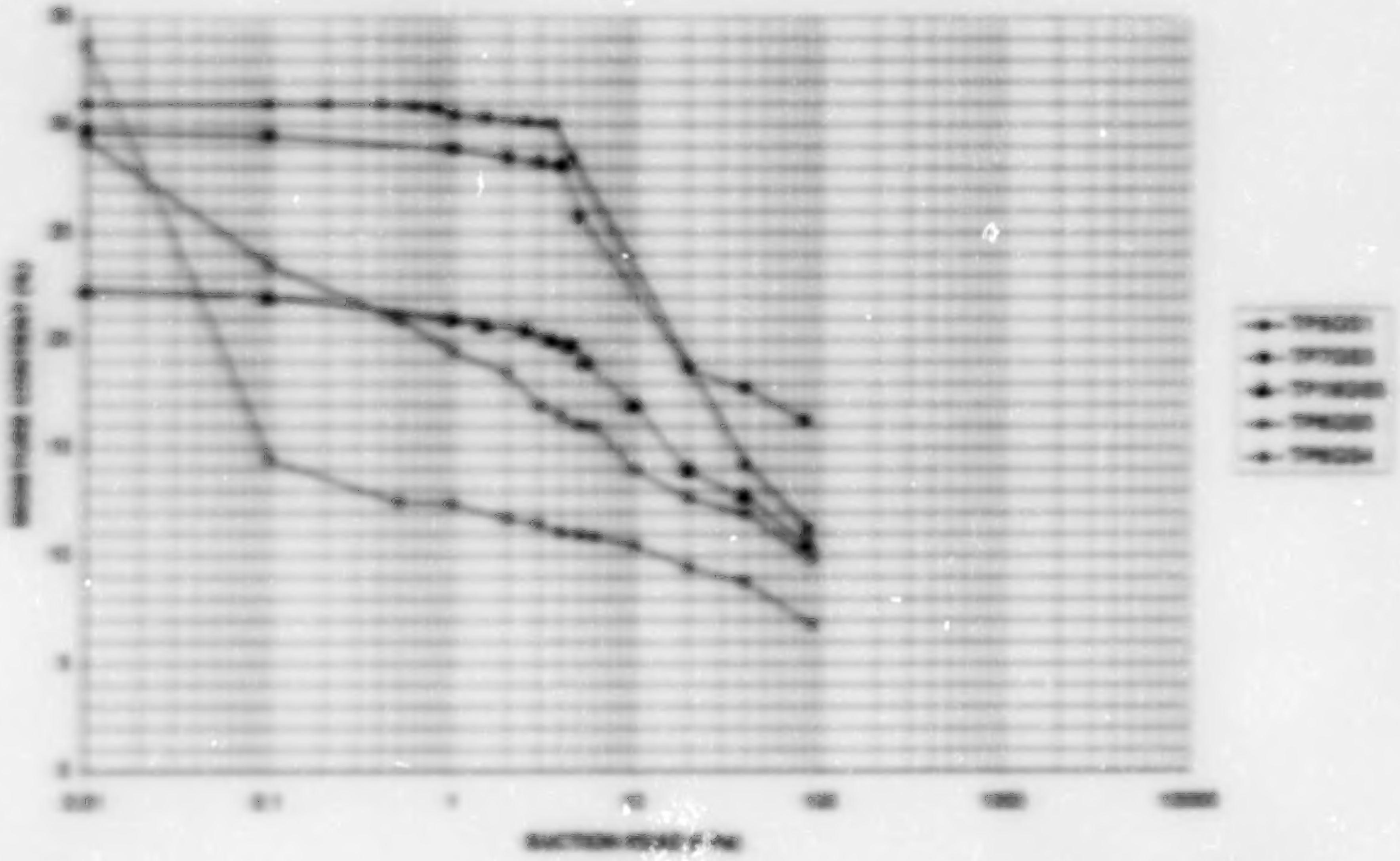

FIGURE J-2

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Estimates of θ_r Based on 100 kPa point, Soil Moisture Retention Curves - University of Saskatchewan. Wilson (1996a) states that the residual volumetric water contents for samples of the waste rock were between 10 percent - 15 percent (6-9 percent gravimetric). Subsequent communications (Wilson 1996b) indicated the following:

1. This estimate of θ_r was derived from the 100 kPa point on the moisture retention curve for the TP7GS3 sample. The 100 kPa soil suction level is slightly greater than field capacity (33 kPa), but significantly less than the soil wilting point (1,500 kPa). Most soil scientists would agree that soil moisture movement can occur at soil suction levels below the wilting point, so the choice of 100 kPa probably predicts too much soil moisture storage before flow commences.

2. The TP7GS3 sample was the finest-grained of the five samples tested. While the fine-grained soils may exhibit high residual water contents, the fine-grained material is not representative of the entire dump. The wetting requirement of the dump will be associated with a mixture of coarse-grained and fine-grained materials, which may have much lower residual water contents. The time of travel calculations through the waste rock dumps would be smaller for materials having lower residual water contents.

Estimates of θ_r Based on RETC Computer Code. These laboratory measurements were provided to the EIS reviewers for five of the waste rock samples. Using the EPA's RETC computer program, the residual moisture contents (θ_r) of four samples were estimated as follows: 0.053 (TP18GS5), 0.08 (TP5GS1), 0.09 (TP4GS4), and 0.16 (TP7GS3). The calculated water content Sample TP6GS5 was so low that the EPA code set the θ_r value to zero. This is often the result for porous materials which have a broad, smoothly ranging pore size distribution.

Estimates of θ_r Based on Rawls Equation. An alternative means of calculating the residual moisture content is to use the field capacity and wilting point to determine the specific retention using the Rawls equation. Field capacity is defined as the volumetric water content at soil water suction of 0.33 bars (33 kPa), or remaining after about three days of gravity drainage. The wilting point is defined as the volumetric water content at 15 bars (1,500 kPa), or the lowest volumetric water content that can be achieved by plant transpiration. These two parameters (θ at 33 and 1500 kPa) can be used to calculate the soil water retention at any intermediate suction head, using the Rawls regression equation for θ_r (Rawls et al. 1982) and the Brooks-Corey equation for θ as a function of head.

The Rawls equation for the relationship of θ_r to wilting point is given by:

$$\theta_r = 0.014 + 0.25\,(W.P.)\ ,\ \text{for } W.P. \geq 0.04$$
$$\theta_r = 0.6\,(W.P.)\ ,\ \text{for } W.P. < 0.04$$

Based on the University of Saskatchewan data, as shown on Figure J-2, the five soil samples have wilting points greater than 0.04, so the first equation applies. The wilting point values and specific retention are given in the following table:

θ_{wp}	θ_r
0.19	0.062
0.15	0.052
0.13	0.047
0.125	0.045
0.09	0.037

The range of values may be attributed to the normal variability in homogeneous soil/rock.

Estimates of θ_r Based on Soil Type. The material in the dumps is a sandy silty loam (Wilson 1996a). Based on 666 samples, the average specific retention of a sandy loam is 0.041, with a range (one standard deviation) of -0.024-0.106 (Rawls et al. 1982). Based on 1,206 samples, the average specific retention of a silt loam is 0.015, with a range (one standard deviation) of -0.029-0.058. Based on 689 samples, the average specific retention of a silty clay loam is 0.040, with a range (one standard deviation) of -0.038-0.118.

However, the soil characteristics determined by Rawls and other soil scientists is based primarily on natural soils. Wilson (1996b) points out that the characteristics of the waste rock are different from those of naturally-weathered soils. The waste rock in the GSM dumps has a higher osmotic pressure, according to Wilson (1996b), and more moisture is required to wet the material than for a natural, in-situ soil which has been exposed to moisture for some time.

Validation of θ_r Estimates Based on Neutron Probe Data

The neutron probe data (Schafer and Associates 1995) indicates that a wetting front moved through the West Dump Site 2, during the period from 9/17/92-6/30/93. Soil moisture movement occurred through some zones having volumetric water contents as low as 0.075. Much of the flow occurred through zones having water contents ranging from 0.08 to 0.10.

At West Dump Site 3, soil moisture movement appears to have occurred at volumetric contents of less than 0.07 within the upper 10-20 feet of the reclaimed dump. In fact, the 24-foot monitoring probe indicated an increase in water content, while the water content at the 22-foot probe never exceeded about 0.053. This indicates that water has moved through the waste rock at moisture contents of less than 0.16.

The West Dump Site 7 probably makes the strongest point for a low value of specific retention. That pile experienced a slight increase in volumetric water content at its base, from about 0.050 to 0.052, with at least 10 feet of overlying waste rock cover. The 5- to 10-foot interval exhibited a similar, minimal moisture increase. Evidently, water was transmitted to the lower zones of the profile through the 5 to 10-foot interval, even though the water content in that interval increased only from about 0.049 to 0.052.

The East Dump test plot F (unreclaimed) also showed increases in moisture at depth, with volumetric water contents in the overlying material as low as about 0.055. While the reclaimed dump will received less infiltration than the unreclaimed test plot, soil moisture movement can occur at these low moisture contents in either case.

These field observations indicate that the waste rock material will transmit water at volumetric water contents less than 0.08.

θ_r Estimates used by Schafer and Associates. The specific retention identified by Schafer and Associates for input to the Schafer spreadsheet model of infiltration through the waste rock dumps was 0.055.

θ_r Estimates used to Compute Travel Times. In summary, residual volumetric water contents, θ_r, for the waste dump materials are estimated to range from 0.04 to 0.10 (4-10 percent). The calculations presented in the following travel time analyses are based on a value of $\theta_r = 0.08$, which is considered to be a reasonable average for all dump materials.

2.2.3 Analysis

Time of Wetting - Waste Rock Dump Materials

The length of time required to wet the waste rock materials to a residual volumetric water content $\theta_r = 0.08$ was determined by Equation (1). Using the following input parameters defined for Equation (1): $\theta_i = 0.05$, $h = 300$ feet, $I = 0.5$ in/yr $= 0.0417$ ft/yr, the time required to wet the waste rock material is:

$$t_w = \frac{0.08-0.05}{0.0417\ ft/yr}\,300\ feet = 216\ years$$

Using a lower infiltration rate (I = 0.25 in/yr = 0.0208 ft/yr), the time required to wet the waste rock material is:

$$t_w = \frac{0.08-0.05}{0.0208\ ft/yr}\,300\ feet = 433\ years$$

At the maximum (pre-reclamation) infiltration rate of I = 2 in/yr = 0.1667 ft/yr:

$$t_w = \frac{0.08-0.05}{0.1667\ ft/yr}\,300\ feet = 54\ years$$

Assessment of Time to Wetting Calculation - Field Data, GSM 1995 Annual Report

An evaluation of "reasonableness" of the time to wetting estimate was made by reviewing the volumetric water content changes in the dumps as represented by neutron probe moisture profiles in Figures 2.2 through 2.17 in the GSM 1995 Annual Report. These graphs appear to indicate a general wetting trend in the dumps that can be observed to advance in depth with time at some locations. Figure 2.1 in that report shows a water balance for the monitored sites between July 1992, and January 1996. The change with time in stored water content over the measured depth of each profile is plotted on Figure 2.1.

At Site 1, which is a reclaimed dump top, the amount of water that accumulated in the measured 70 feet profile depth over the 3.5-year period was approximately 12 inches. This cumulative stored water corresponds with an average change in volumetric water content ($\Delta\theta$) of 0.014 over the 70-foot profile.

An advancing wetting front could be observed from the data at Site 1. The wetting front migrated roughly 25 feet in 2 years (between depths of 20 to 40 feet in 1993 to depths of 45 to 65 feet in 1995). The moisture advance occurred across several variably textured zones, which had different initial and "post wetting front" residual moisture contents. However, if it is assumed that the average "wetting requirement" ($\Delta\theta = \theta_f - \theta_i$) is equal to the average change in water content (0.014) over the wetting front advance interval of approximately 25 feet in 2 years, the rate of infiltration is

$$I = \frac{0.014}{2yrs}\,25ft = 0.175ft/yr = 2.1inch/yr$$

This rate of infiltration was predicted for the dumps prior to the establishment of vegetation. Once the reclamation caps are fully vegetated, the expected infiltration rates are anticipated to reduce to between 0.25 and 0.5 in/yr.

The "wetting requirement" for Site 1 was relatively small (0.014) because the initial moisture content at the time of the initiation of moisture measurements was substantially higher than the 0.05 "typical" value assumed in the previous calculations. On average, the wetting requirement for the dumps is expected to be approximately 0.03, or 3 percent, and the time to wetting calculations presented previously are considered reasonable.

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Steady State Seepage

The mixing cell model is started at t_w = time to wetting, corresponding to the amount of time required to fulfill a wetting requirement of 3 percent. The time to wetting is computed from Eq. 1, as outlined in the previous section. Recharge to the model is initiated after an offset of this amount of time. Recharge is assumed to be at a constant rate, given by the steady downward flux (q). The maximum total flux (q_{max}) during steady-state, unsaturated flow is assumed to be equal to the infiltration rate (I). However, the maximum recharge cannot exceed the hydraulic conductivities of the materials. Runoff, probably in the form of isolated springs or seeps, will occur when the infiltration rate exceeds the hydraulic conductivity of the materials.

East Dump Travel Times. On the east side, the time required for a "particle" of ARD-impacted water to seep from the base of the dump to the water table through the vadose zone is computed using Eq. 2. The vadose zone travel time plus the time to wetting of the waste dump, gives the total time before any ARD is introduced to the aquifer. The time of travel through the vadose zone beneath the East Dump is dependent on the soil's unsaturated hydraulic properties. The following hydraulic material characteristics were assigned to the Bozeman Formation, a dense silty clay which underlies the East Dump waste rock fills:

PARAMETER	DESCRIPTION	VALUE	DATA SOURCE
θ_s	Saturated volumetric water content	0.452	USDA soil texture average for dense silty clay
θ_{fc}	Field capacity	0.411	average for dense silty clay
θ_{wp}	Wilting point	0.311	average for dense silty clay
θ_r	Specific retention	0.092	Rawls equation
K_s	Saturated hydraulic conductivity	1.2E-6 cm/sec	Infiltration parameters for dense silty clay
n_e	Effective porosity	0.26	average for dense silty clay

The maximum (saturated) hydraulic conductivity of the Bozeman Formation is 1.2E-6 cm/s = 15 in/yr. This hydraulic conductivity exceeds the maximum infiltration rate (2 in/yr) that was assumed for the various infiltration scenarios. Thus, for the East Dump evaluations, the vertical flux was assigned to equal the infiltration rate, with no ponding or runoff.

Travel time through the Bozeman Formation vadose zone is computed from the seepage velocity (v), given by Equation (2). The upper bound (shortest) time of travel possible through the vadose zone below the dumps corresponds with the maximum (saturated) hydraulic conductivity (K_s), as follows:

$$v = \frac{q}{\theta_e} = \frac{K_s i}{n_e} \qquad (3)$$

where:
i = hydraulic gradient
n_e = effective porosity

Assuming a vertical gradient i = 1.0, and the material characteristics summarized on the previous table, the maximum seepage velocity would be

$$v = \frac{15 inches/yr \cdot 1.0}{0.26} = 57.7 inches/yr = 4.8 ft/yr$$

Water will seep much more slowly through unsaturated materials because hydraulic conductivity decreases dramatically as water content is reduced. The results of unsaturated flow modeling indicate that the volumetric water content of the Bozeman Formation would be 0.257, for the assumed material properties given above and an infiltration rate of 0.5 inch/year. The seepage velocity under these conditions is calculated as follows:

$$v = \frac{q}{\theta - \theta_r} = \frac{0.5 inch/yr}{0.257 - 0.092}\left(\frac{1 ft}{12 inches}\right) = 0.252 ft/yr$$

Assuming that the depth from the base of the waste rock dump to the water table is 200 feet, the time of travel from the dump base to the aquifer would be approximately 790 years. This result is sensitive to the assumed infiltration rate, and to the assumed moisture content of the soil profile at that infiltration rate. The method assumes that no preferential pathways exist, and that soil moisture movement occurs throughout the soil profile, which is considered to be a reasonable assumption for the site conditions.

West Dump Travel Times. Foundation conditions beneath the West Dump are significantly different from the East Dump conditions. The bedrock is overlain by a relatively thin veneer of gravelly soils beneath the dumps. It is assumed that seepage which infiltrates the West Dump waste piles in excess of 0.5 inch per year will run off the shallow bedrock surface, and will not contribute to the groundwater recharge.

2.2.4 Time of Travel Summary

In summary, the time-of-travel through the waste rock dumps and vadose zone below the dumps was estimated based on predicted hydraulic properties of the materials, and assumed infiltration rates. For an infiltration rate of 0.5 inch per year, the simplified model predicted that approximately 200 years would be required to "wet" the dump to approximately 3 percent above its placement moisture, at which time moisture migration from the dump will commence. Approximately 600 years would be required to achieve this moisture condition throughout the dump material for an assumed infiltration rate of 0.25 inch per year. These values represent the total travel times for ARD on the west side which is not underlain by a thick layer of unsaturated sediments.

A steady-state calculation of the time-of-travel through the Bozeman Formation indicates that, at an infiltration rate of 0.5 inch/yr, approximately 800 years would be required for soil moisture to move from the base of the dump to the top of the water table, some 200 feet below. Therefore, at an infiltration rate of 0.5 inch/yr, the total travel time for ARD on the east side is on the order of 1,000 years.

2.3 Model Results for All Action Alternatives

The results of mixing cell simulations for all action alternatives are presented relative to three different rates of precipitation infiltration into waste rock dumps. These different infiltration estimates represent a bracketed measure of the success of reclamation practices at the Golden Sunlight Mine. The three infiltration rates for dump surfaces considered in the mixing cell model are

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- Best Case- 0.25 in/yr based on Golden Sunlight Mine evaluations using numerical models (e.g., HELP and SOIL COVER)

- Worst Case- 2 in/yr based on field data for unreclaimed dump tops

- Expected Case- 0.5 in/yr based on consideration of reduced infiltration on dump slopes (~0.25in/yr) relative to dump tops (~2in/yr), and the relative exposed surface area of each

2.3.1 East Side Locations

Model output for East Side locations for the all action alternatives considered (No Action, Proposed Action, Divided Dump) for the Best, Worst and Expected Case dump reclamation performance scenarios are graphed in Figures J-4 through J-12. The results are grouped by action alternative.

2.3.2 West Side Locations

Model output for West Side locations for the all action alternatives considered (No Action, Proposed Action, Divided Dump) for the Best, Worst, and Expected Case dump reclamation performance scenarios are illustrated in Figures J-13 through J-18. The results are grouped by action alternative.

2.3.3 3:1 Slope Alternative

Model output for the 3:1 slope inclination alternative are shown for the Proposed Action only on Figures J-19 through J-24. Figures J-19 through J-21 are the results for Best, Worst, and Expected dump reclamation performance scenarios for the East Dump, and Figures J-22 through J-24 present these results for the West Dump.

2.4 Discussion of Model Results

2.4.1 Interpreting Model Output

The mixing cell model produces output that describes the concentration of sulfate as a function of time for each of the cells comprising the modeled flow path. An interpretive figure is provided in Figure J-3 which shows in the legend the graph lines that correspond to cells along the flow path modeled. Figure J-3 does not represent any specific modeled alternative and is included as an aid to interpreting figures which represent modeled results for each action alternative.

The graphs of modeled action alternatives provide several schematic features. For any given cell, the modeled concentration of sulfate begins to increase when ARD products begin to arrive. These concentrations can increase to a steady-state value so long as calcite remains in the cell to neutralize acidity and cause gypsum precipitation. When calcite content in a cell is modeled to be exhausted, sulfate concentrations can increase and have a maximum that is limited by simple dilution considerations only. Concentrations of sulfate then can diminish when ARD products cease to be supplied--a condition which is driven by estimates of ARD production lifetime in the dump complexes.

Thus, for each figure representing a modeled action alternative, the reader can follow the trace of any cell (representing a distance from the dump complex) to estimate the modeled sulfate concentration at any point in time. All graphs begin with time zero as the present, and the time axis indicates years in the future.

The cell labeled in the legend as "Jefferson" represents the chemistry of solutions that flow from the end of the modeled flow path and report to the Jefferson alluvial aquifer/surface water system. This is the first major dilution source prior to the Jefferson River. It does not represent the concentration of sulfate expected in the Jefferson River. Flows in the river will greatly dilute the concentration of solutions that come from the modeled flow path.

2.4.2 West Side Performance

The West Dumps have the same dump mass and geometry for both the No Action and the Proposed Action alternatives. Therefore, the impact is the same for both, and graphs are presented for the No Action Alternative only. The model predicts significant increases with time in sulfate concentrations. The time before any water resources impact is anticipated, however, varies with projected infiltration into the waste rock dump. For the worst case scenario for any action alternative, significant impacts could be experienced as soon as about 50 years. Best scenarios delay any impacts for about 350 years minimum. For worst or best case dump infiltration assumptions, concentrations of sulfate rise to similar levels at the end of the modeled flow path.

It is likely that low pH conditions will accompany the crest of rising sulfate concentrations. Because the numerical mixing cell model does not allow the sulfate concentration to rise above 1600 mg/L until neutralization capacity (calcite) has been consumed, the elevated concentrations of sulfate predicted by the model for the west side locations indicate that breakthrough of low pH conditions are likely. Concomitant with the anticipated decrease in pH, an increase in trace metal concentration would be expected, with specific concentrations not unlike the concentrations currently measured in dump interstitial solutions.

The model predicts that the divided dump will produce a greater impact than either the No Action or Proposed Action alternatives. This result is due simply to the increased dump surface area associated with the divided dump alternative which allows more rainfall to contact waste rock. No increase in groundwater recharge area accompanies this increase in dump surface area.

For the worst case dump infiltration scenario analyses (2 in/yr), the formation of localized acidic seeps and springs is anticipated. This results from the difference between modeled 2 in/yr dump infiltration and a limited, 0.8 in/yr, infiltration into vadose zone solids underlying the west waste rock dumps.

2.4.3 East Side Performance

Primarily due to the increased abundance of acid neutralizing material assumed to be present at depth in the aquifer solids on the east side of the mountain, the impacts to groundwater and the end of the modelled flow path are expected to be significantly lower than on the west side, as illustrated in Figures J-4 through J-12. Because sulfate concentrations do not rise above 1600 down gradient of the dumps, a breakthrough of low pH conditions is not anticipated on the east side. Similarly, significant trace metal loading would not be expected.

Travel times for solute transport in the model from aquifer below the waste rock dumps to the Jefferson alluvial aquifer are on the order of 120 years after the ARD has reached the Bozeman aquifer. This value compares favorably with a Darcy's Law estimate of 160 years (Hydrometrics 1996).

2.4.4 3:1 Slope Performance

There is no discernable difference in ARD impacts between the 3:1 and 3:1/2:1 combination of reclaimed slopes for the Proposed Action on the east side, as seen by comparing Figures J-7 through J-9 and J-19 through J-21. A comparison of Figures J-13 through J-15 and J-23 through J-25 shows that the 3:1 slope alternative does result in higher predicted concentrations of ARD occurring at sooner times on the west side. This is especially evident under the Worst Case infiltration scenario, where concentrations of sulfate are predicted to rise over 15,000 mg/L at the end of the modelled flow path for the 2:1 dump slopes compared with maximum levels of less than 8000 for the 3:1 reclaimed slopes.

2.4.5 ARD-Associated Metals Concentration Estimates

Maximum metal concentration range estimates are summarized on Table J-5. In Table J-5, "BG" indicates background concentration as a lower limit. Table J-5 reports the results that were estimated for the No Action Alternative. Maximum concentrations were estimated from the Worst Case infiltration scenario. All other alternatives are estimated to fall within the same range of concentrations. No distinction can be made among alternatives in terms of potential metal concentrations, because of the relatively small differences in maximum sulfate concentrations predicted by the mixing cell model for the Worst Case scenario. The differences in maximum sulfate concentrations among the alternatives are not sufficient to allow reasonable detection of differences in metals concentrations given the approximate nature of the simplistic metal-sulfate correlation analyses. The approximate times to reach the maximum sulfate and metals concentrations on the east and west side areas also are indicated on Table J-6 below.

Table J-6

Summary of Maximum ARD-Associated Metals Concentration Ranges
No Action Alternative

	Maximum Concentration (ppm)					Time Frame (years)
	As	**Cd**	**Cu**	**Mn**	**Zn**	
East Side	BG[1] - 2.0	BG - 0.2	BG - 100	BG - 80	BG - 43	~1200
West Side	BG - 2.0	BG - 0.15	BG - 105	BG - 55	BG - 29	~750

[1]BG = background concentration

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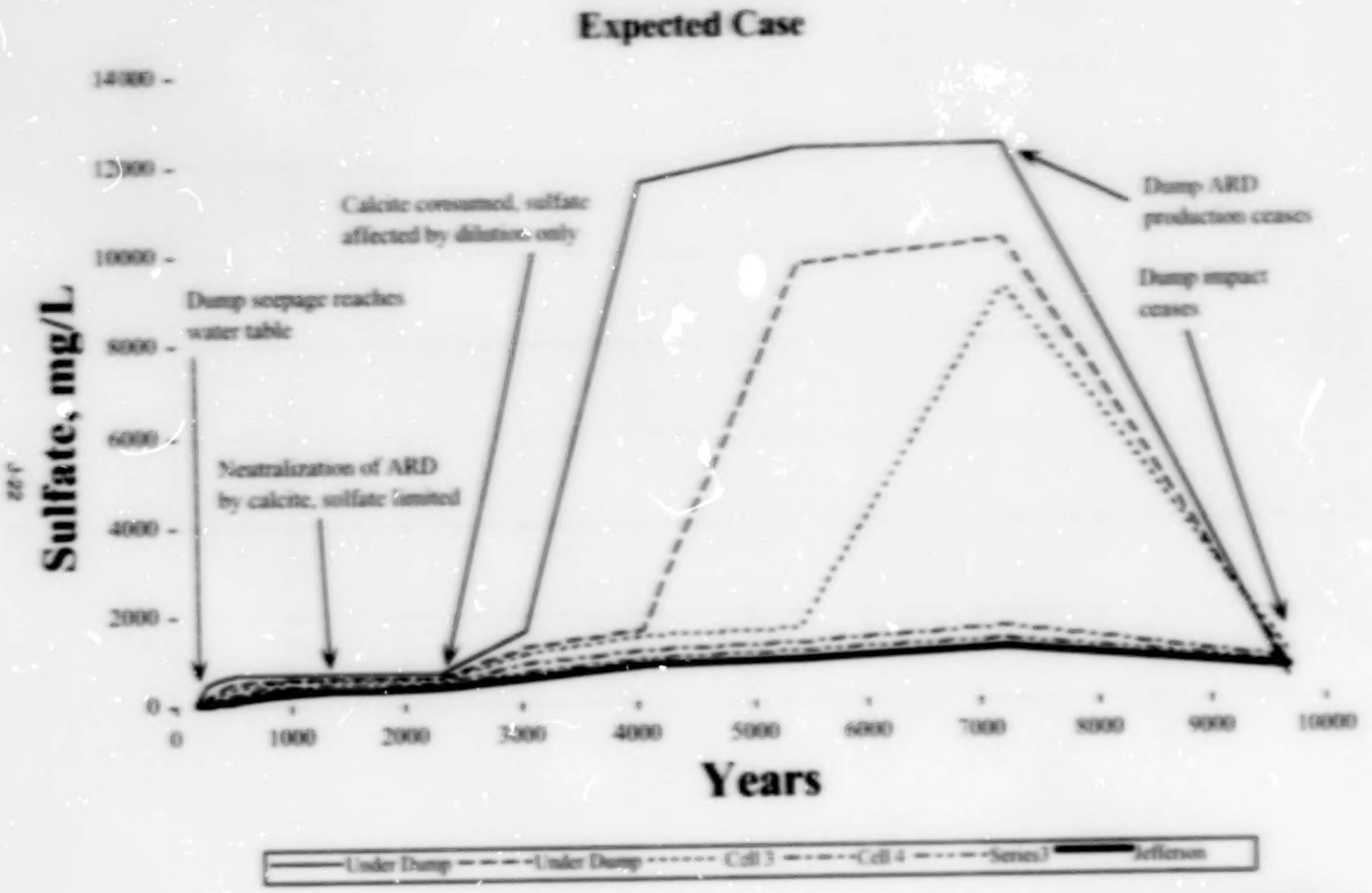

FIGURE J-3

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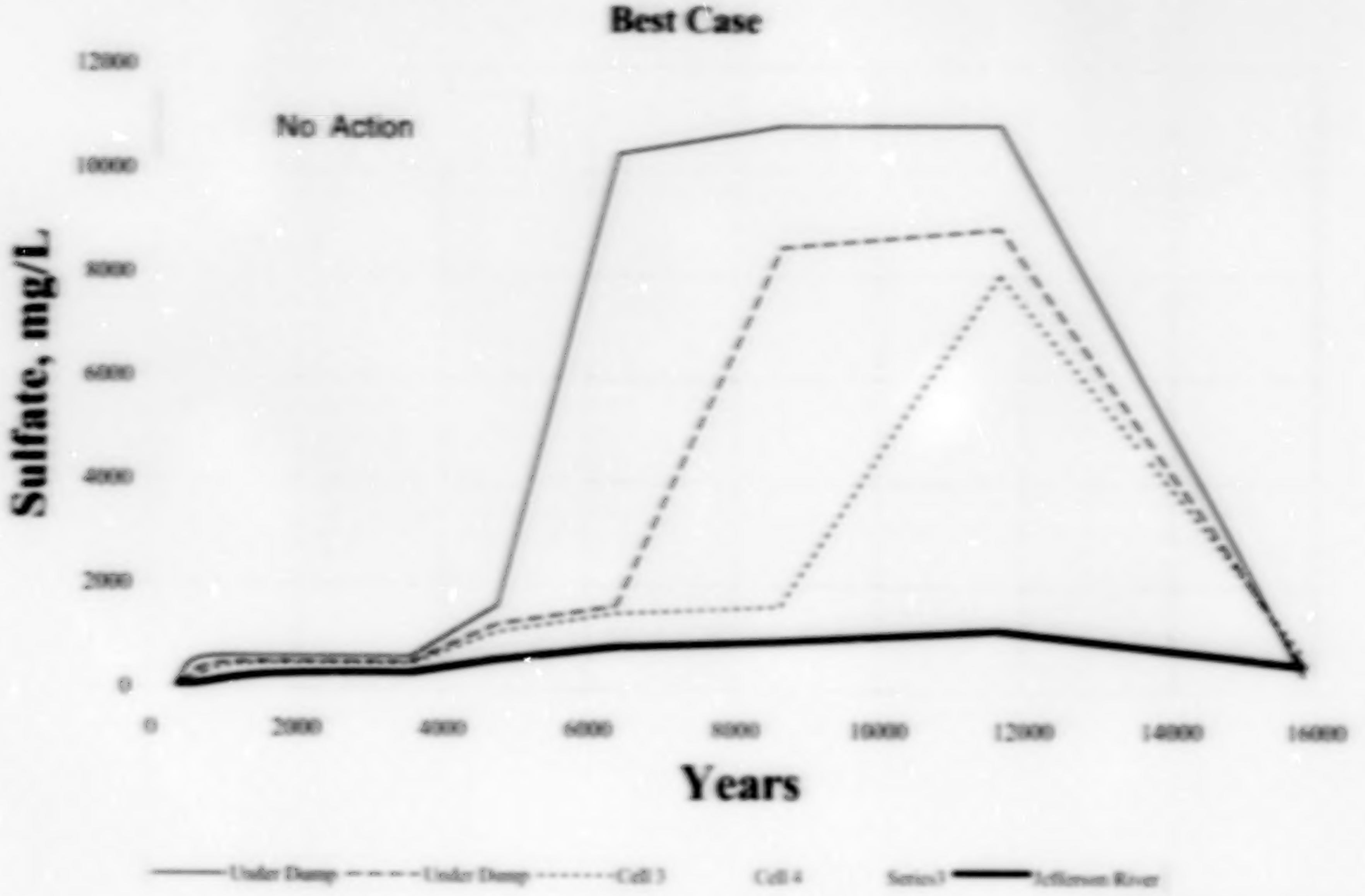

FIGURE J-4 (East Side)

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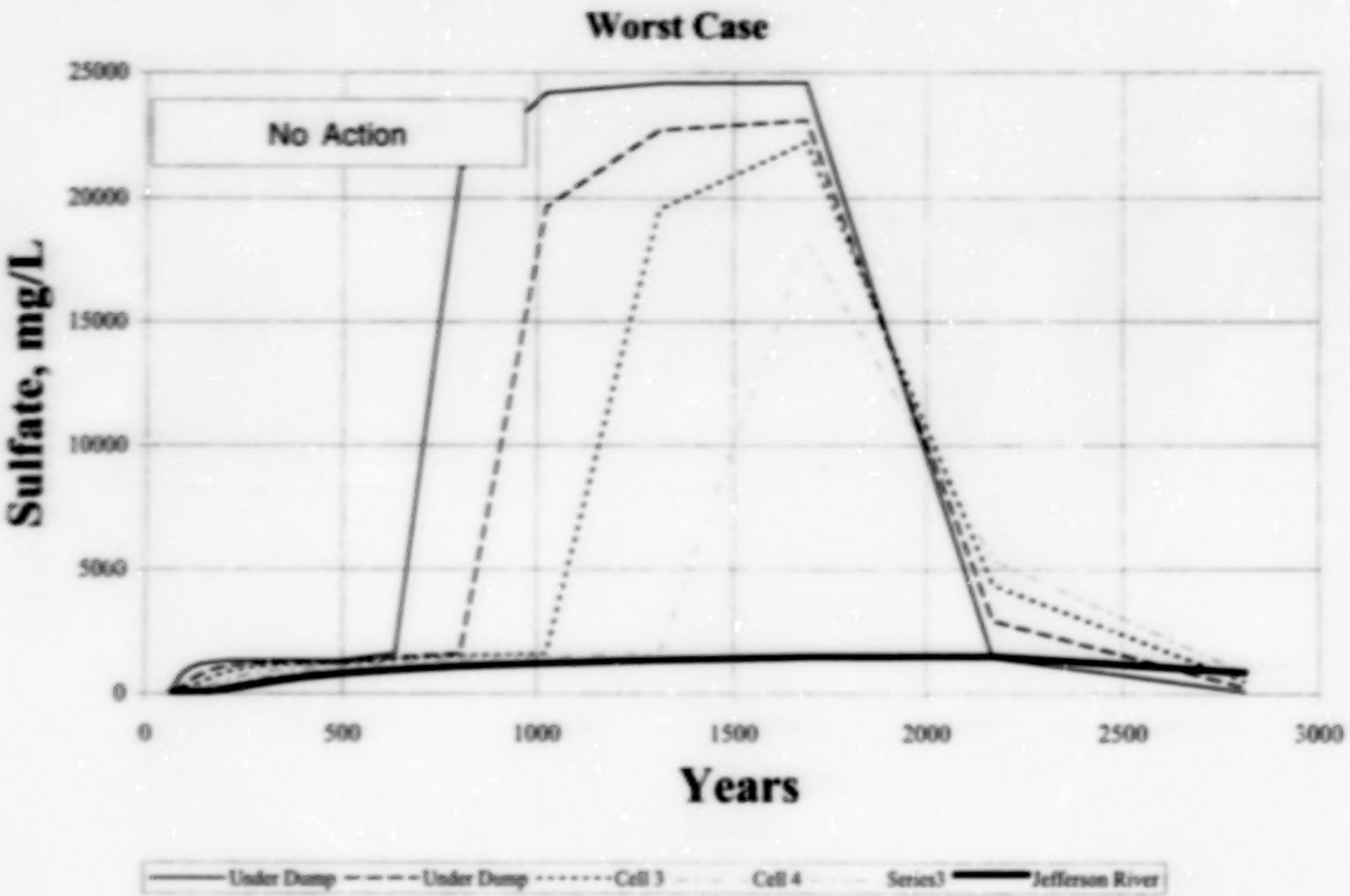

FIGURE J-5 (East Side)

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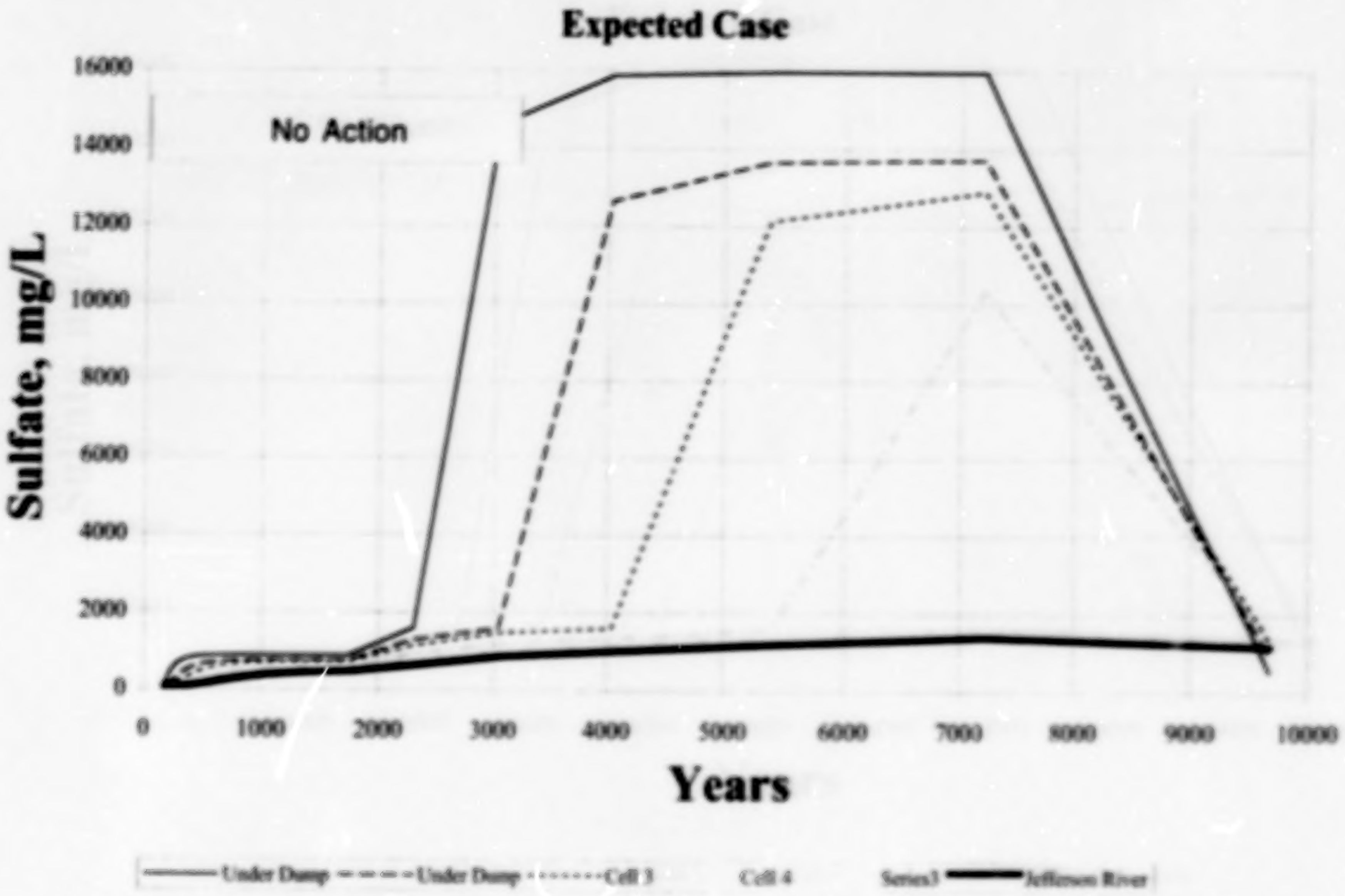

FIGURE J-6 (East Side)

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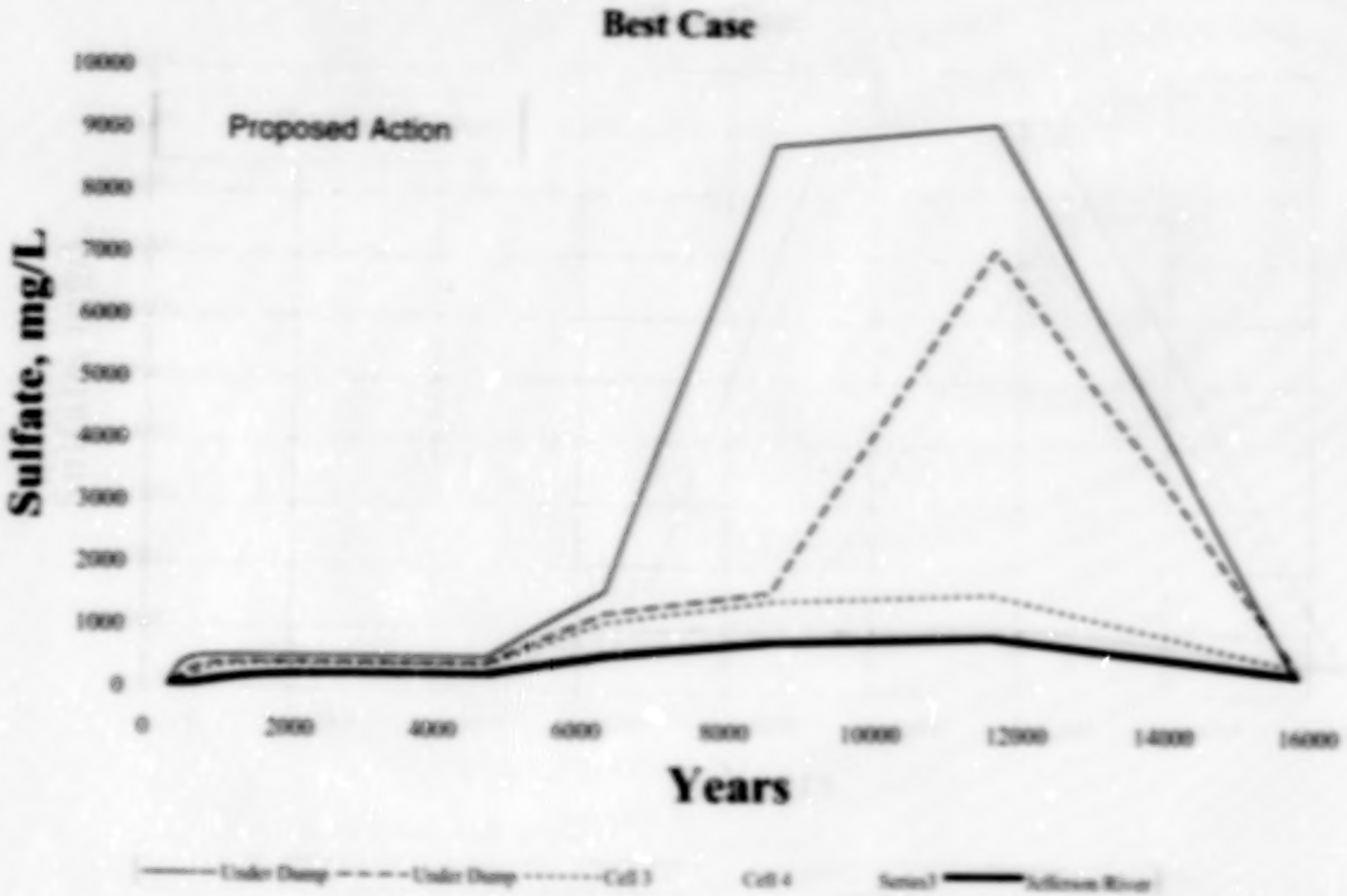

FIGURE J-7 (East Side)

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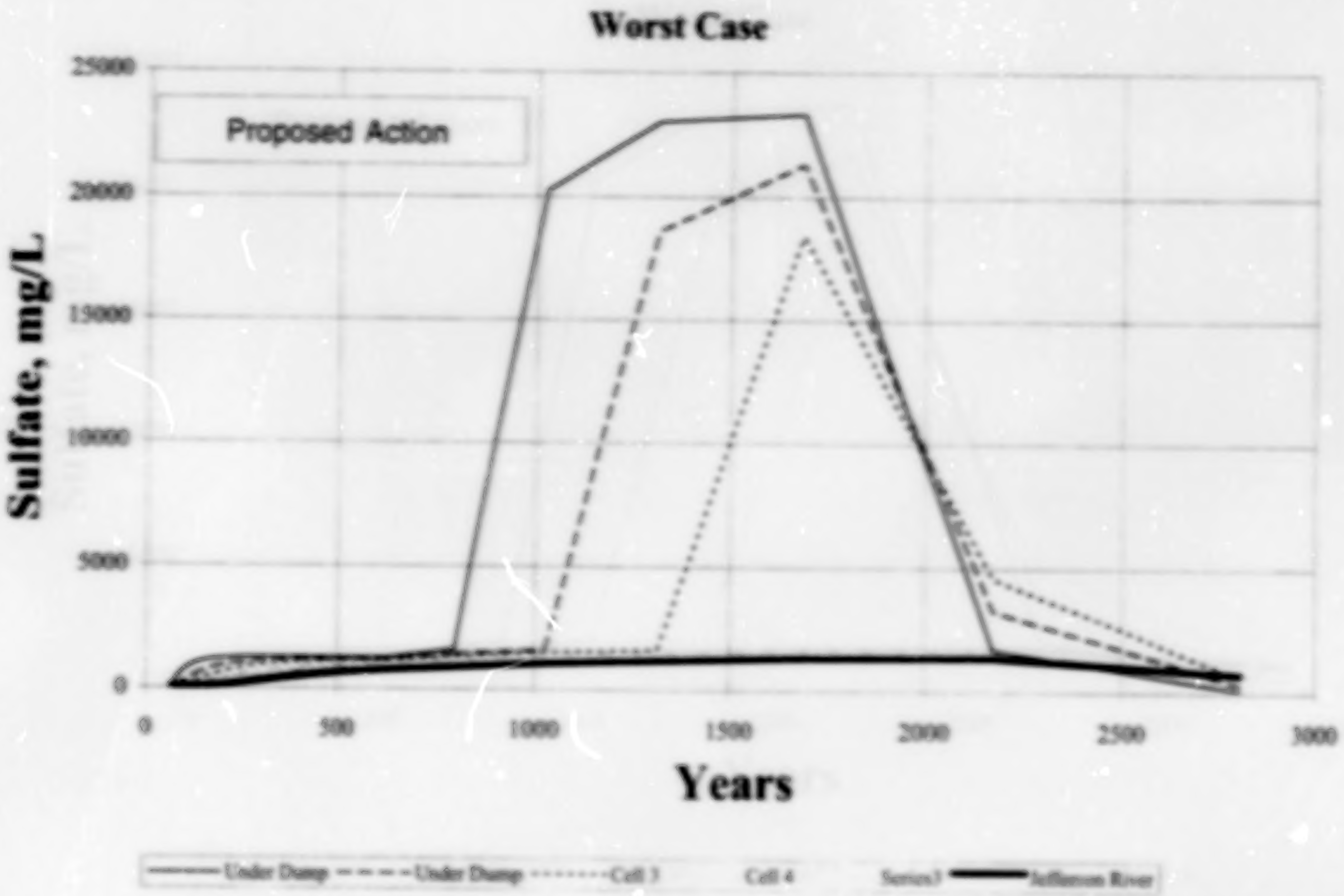

FIGURE J-8 (East Side)

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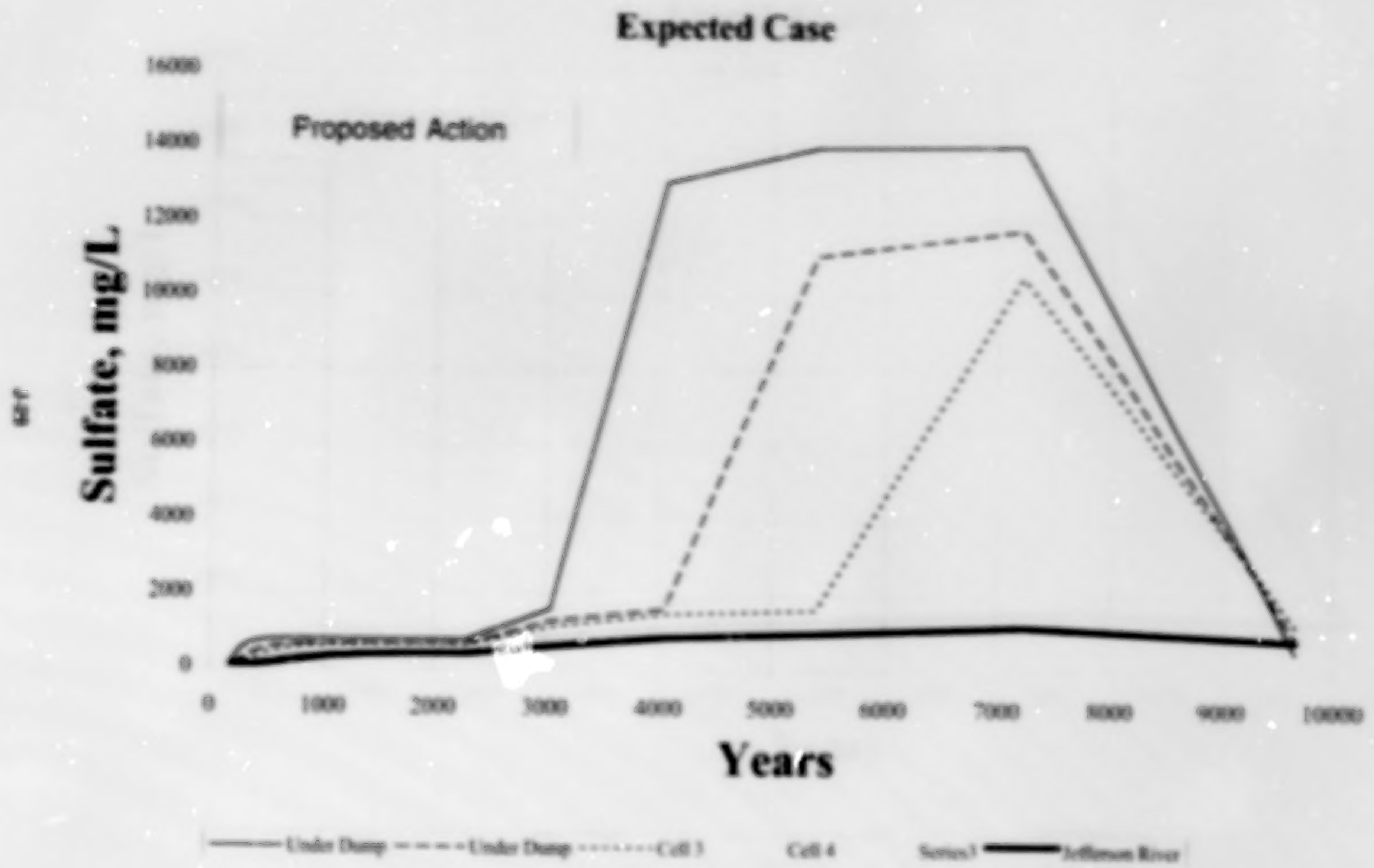

FIGURE J-9 (East Side)

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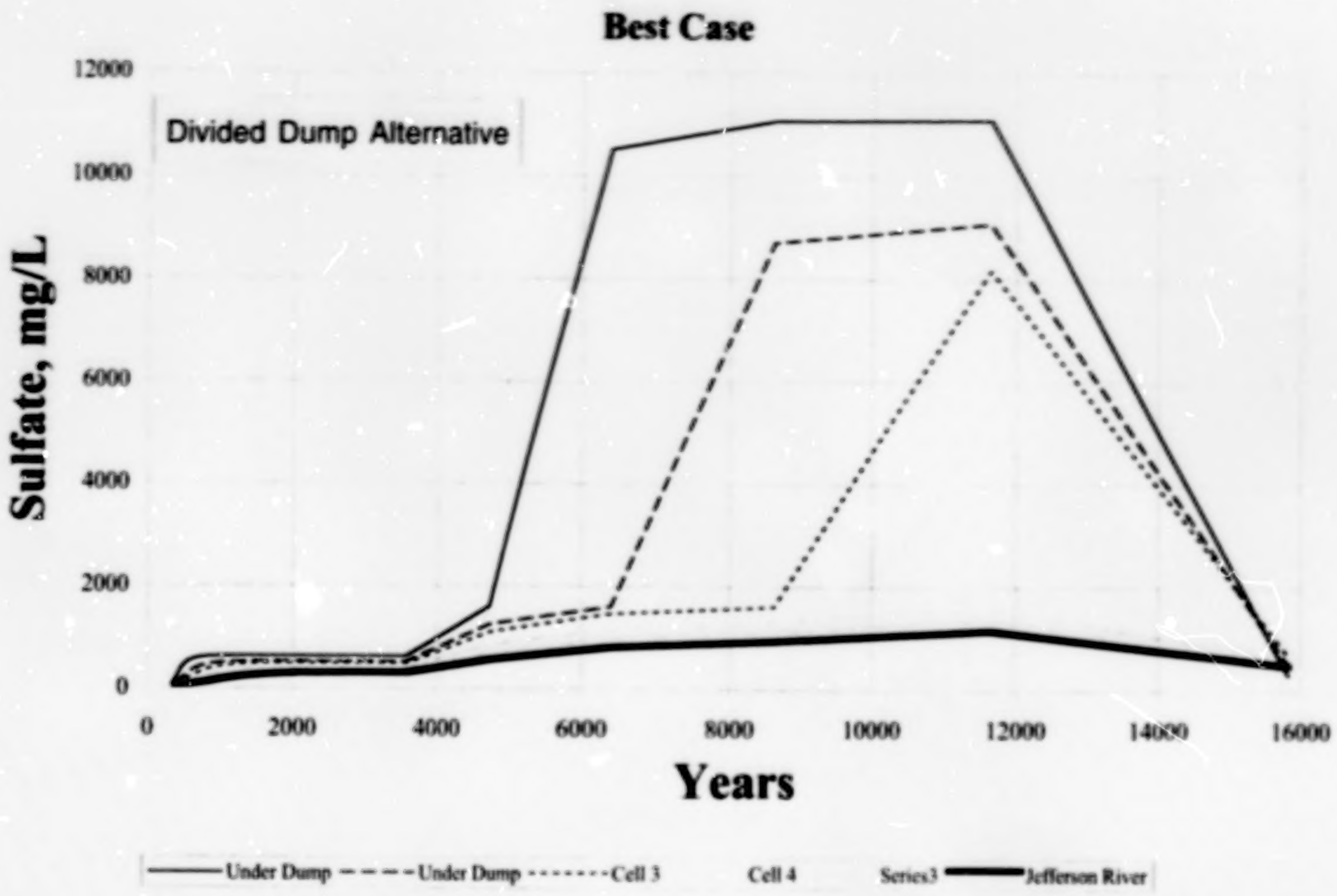

FIGURE J-10 (East Side)

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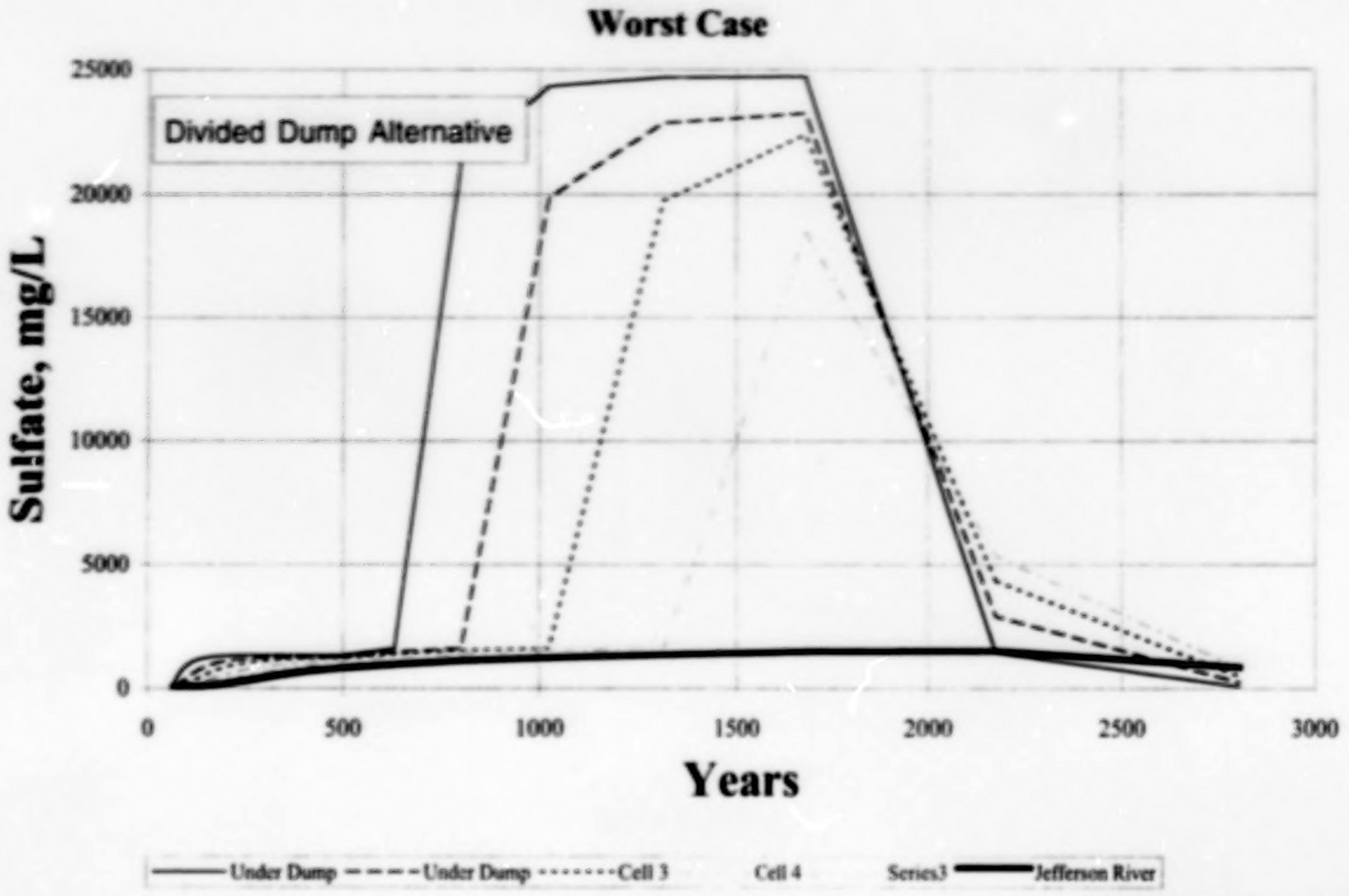

FIGURE J-11 (East Side)

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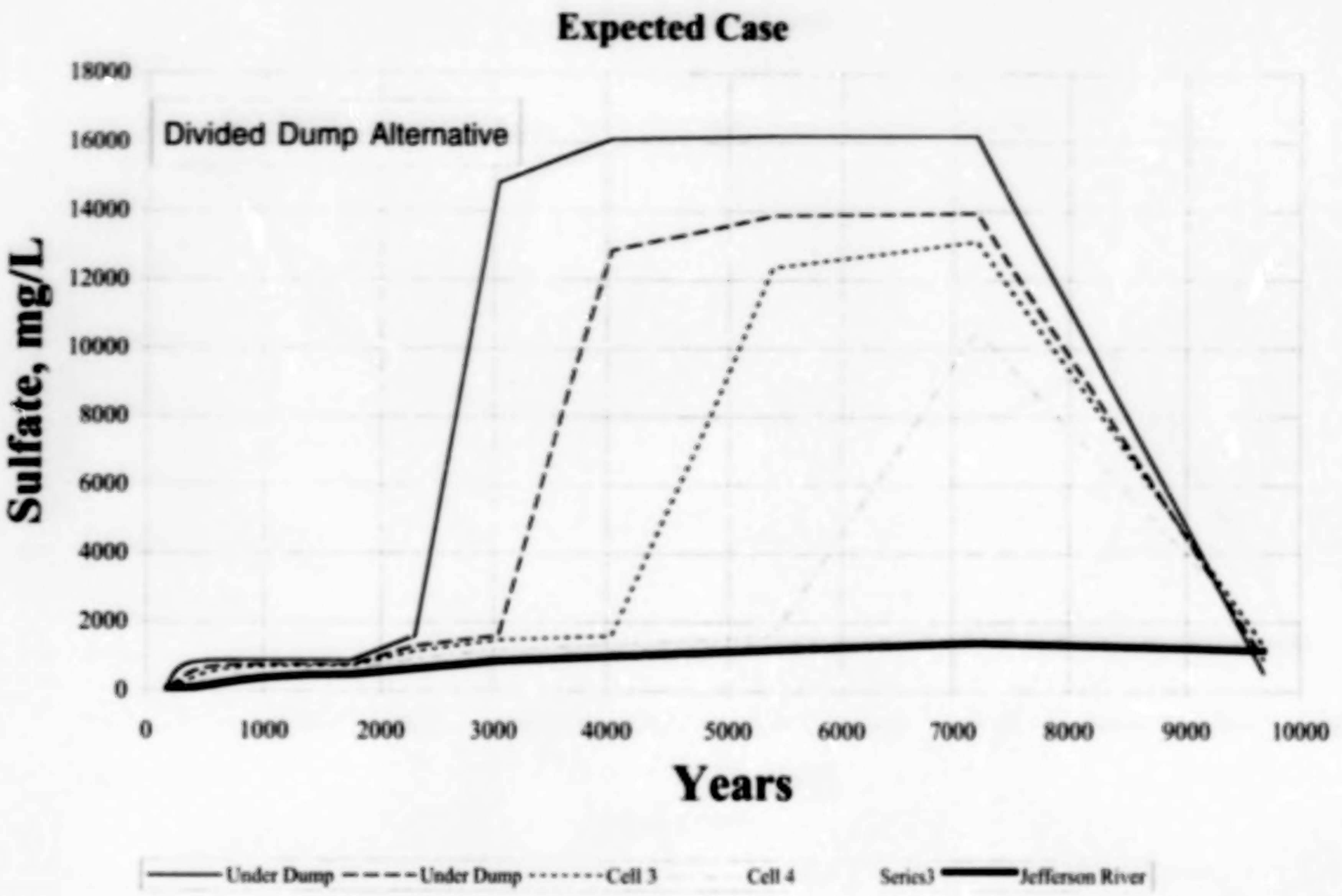

FIGURE J-12 (East Side)

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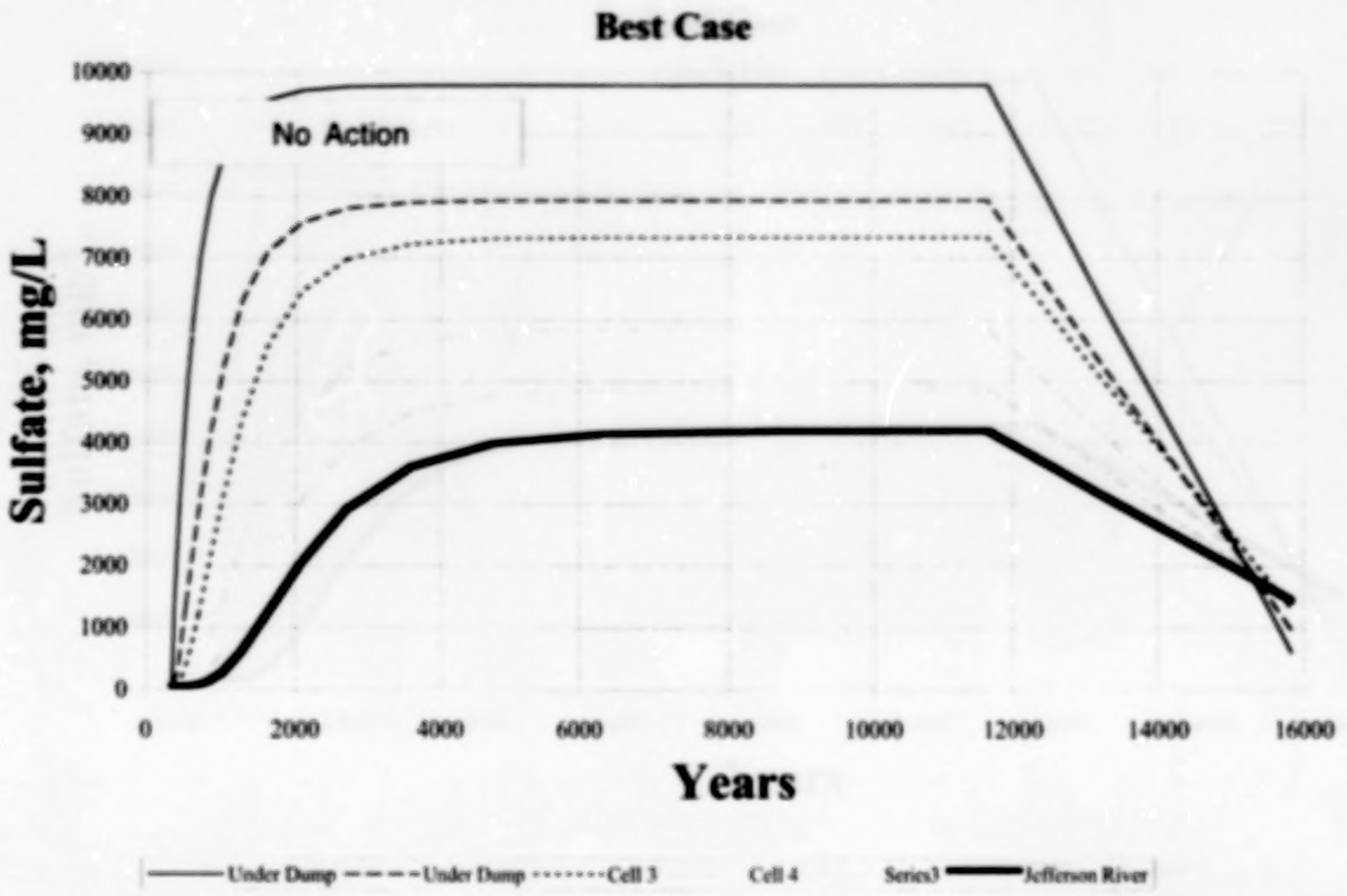

FIGURE J-13 (West Side)

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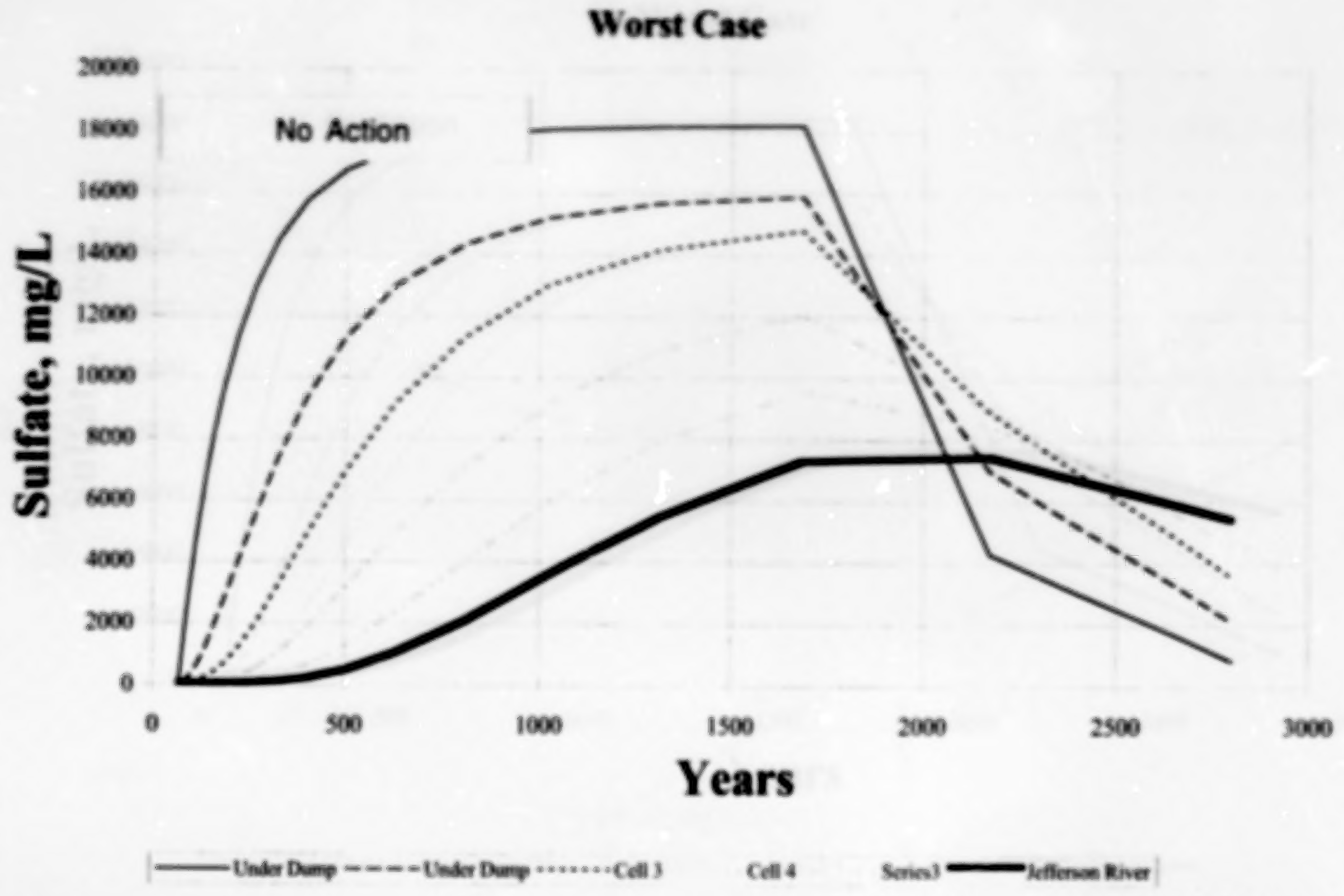

FIGURE J-14 (West Side)

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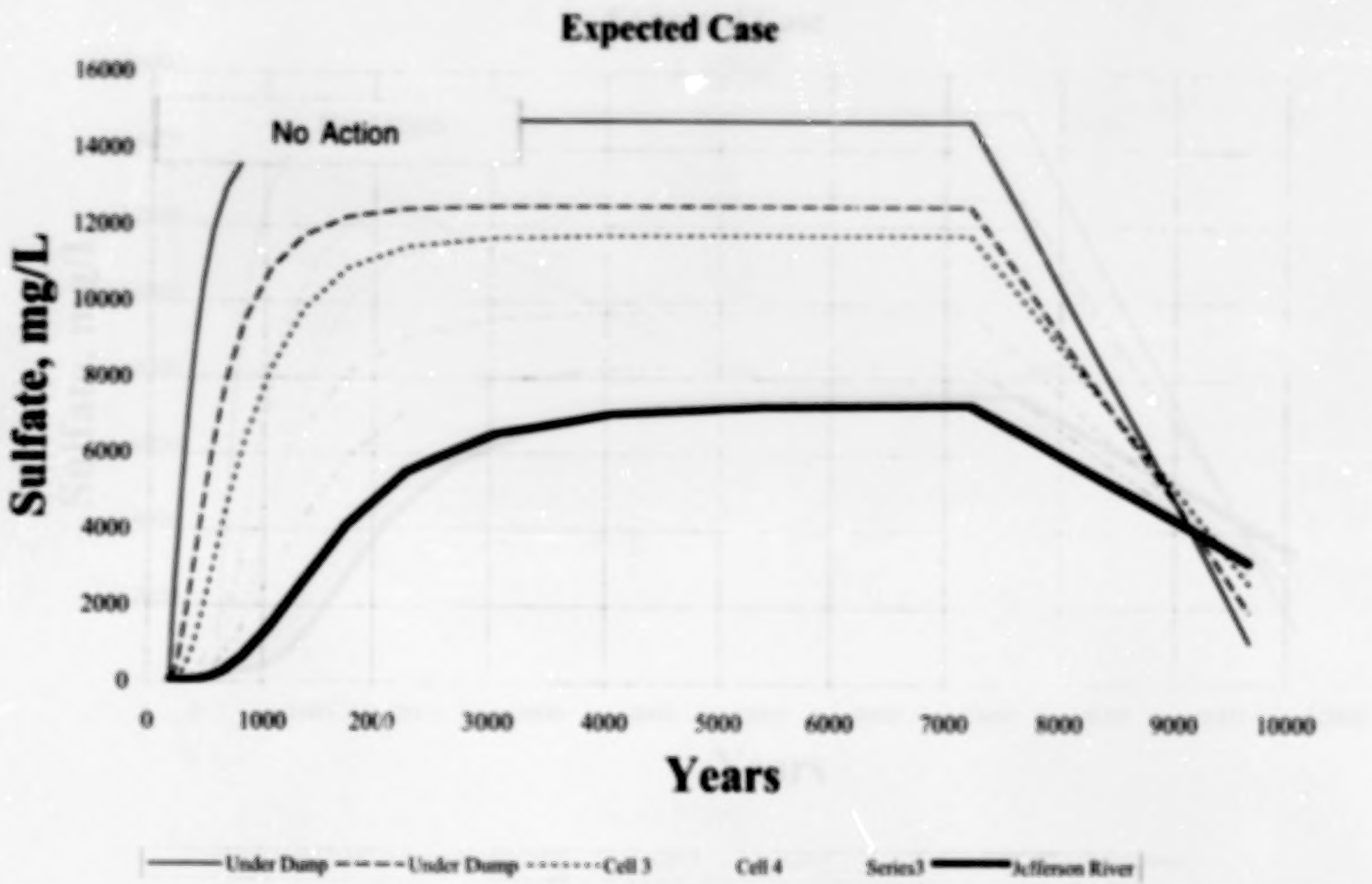

FIGURE J-15 (West Side)

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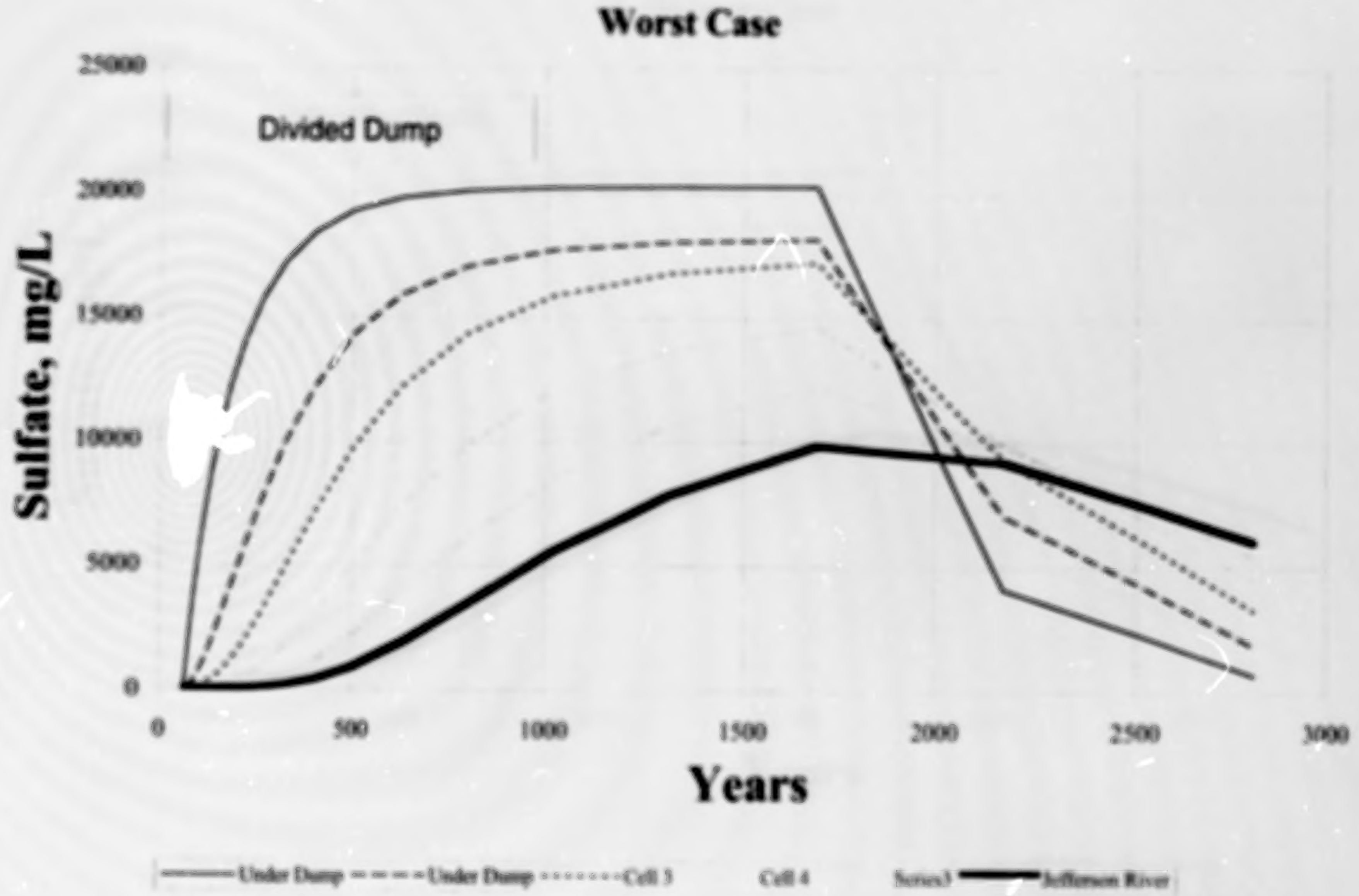

FIGURE J-16 (West Side)

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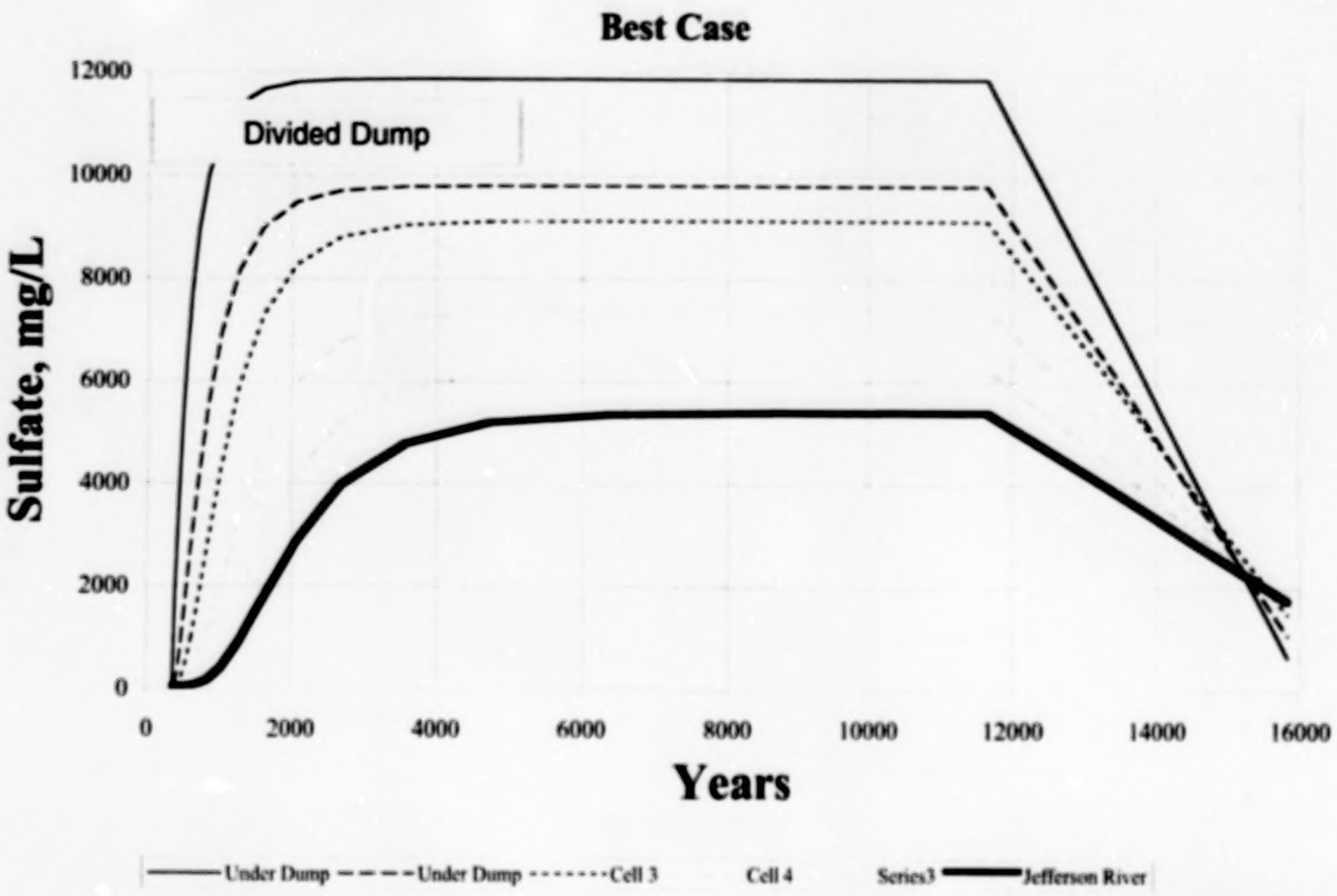

FIGURE J-17 (West Side)

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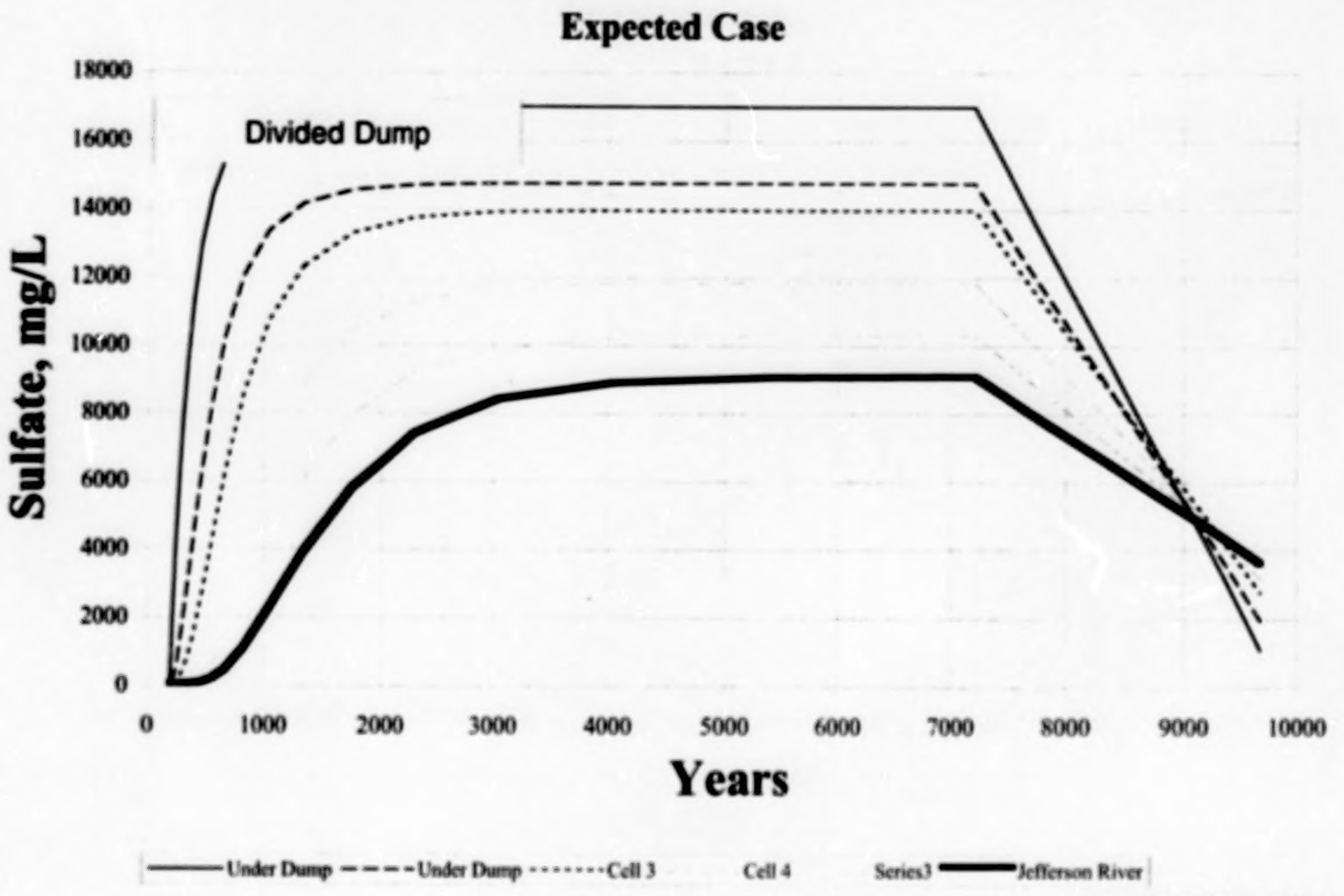

FIGURE J-18 (West Side)

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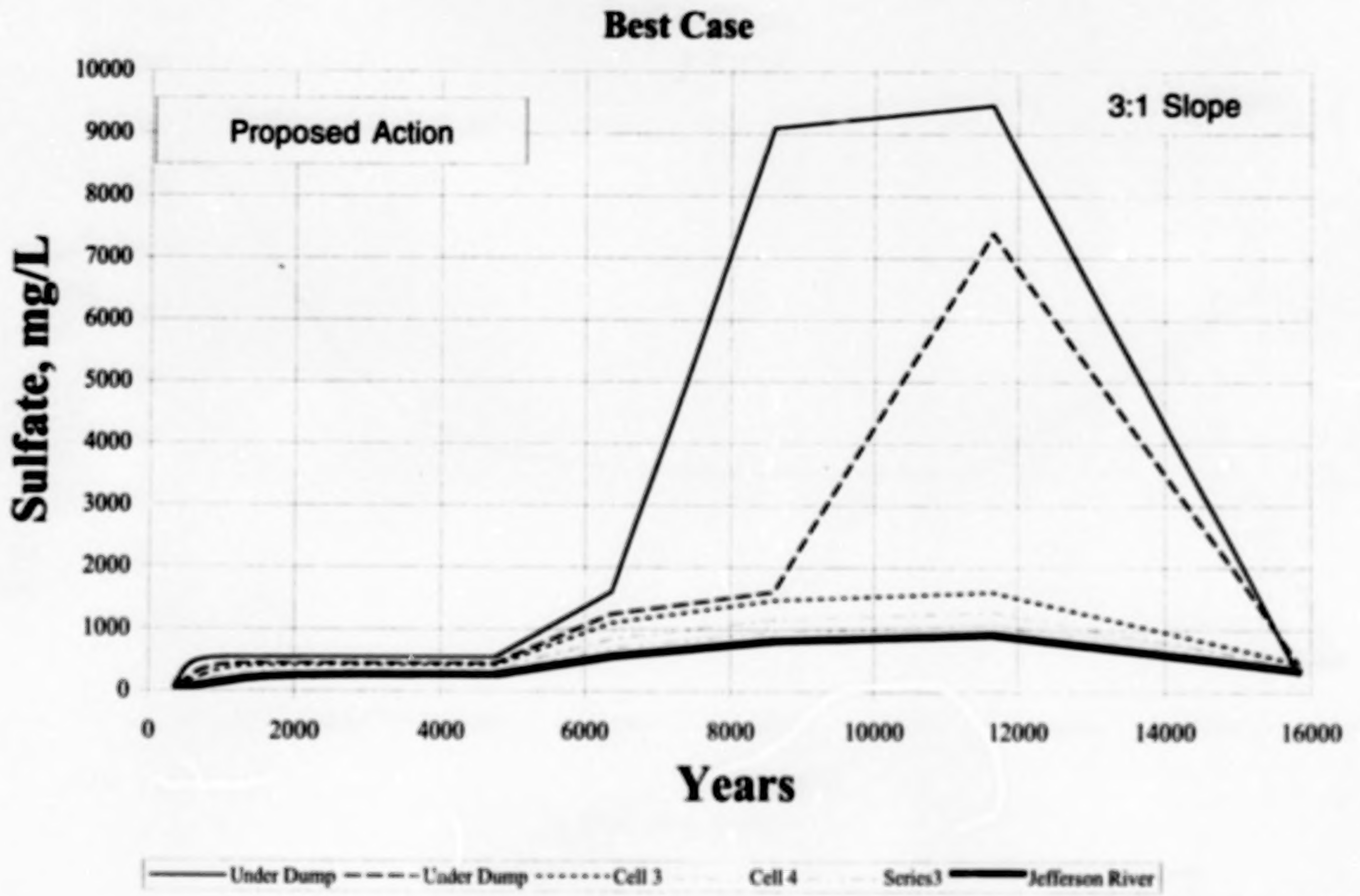

FIGURE J-19 (East Side)

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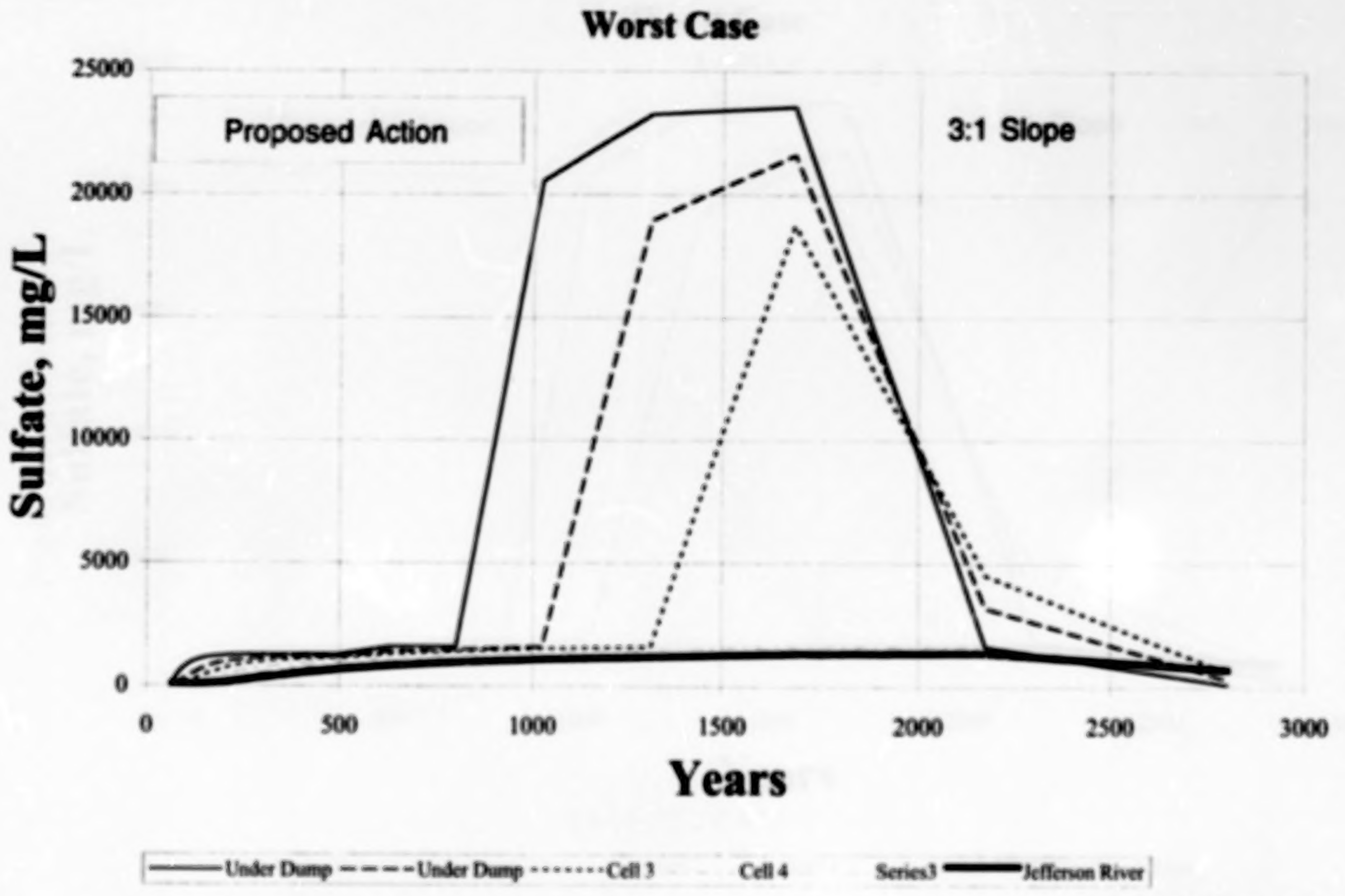

FIGURE J-20 (East Side)

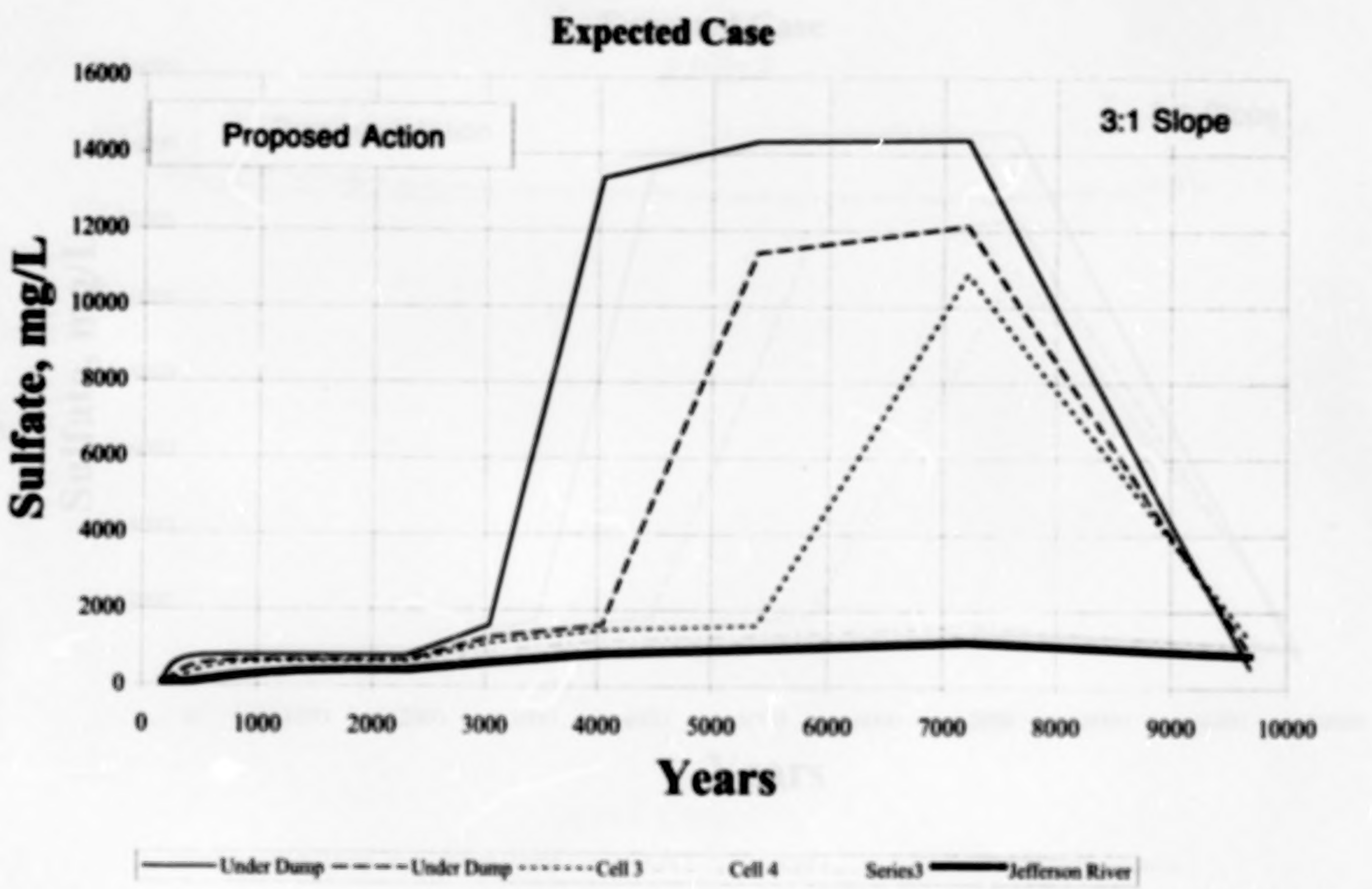

FIGURE J-21 (East Side)

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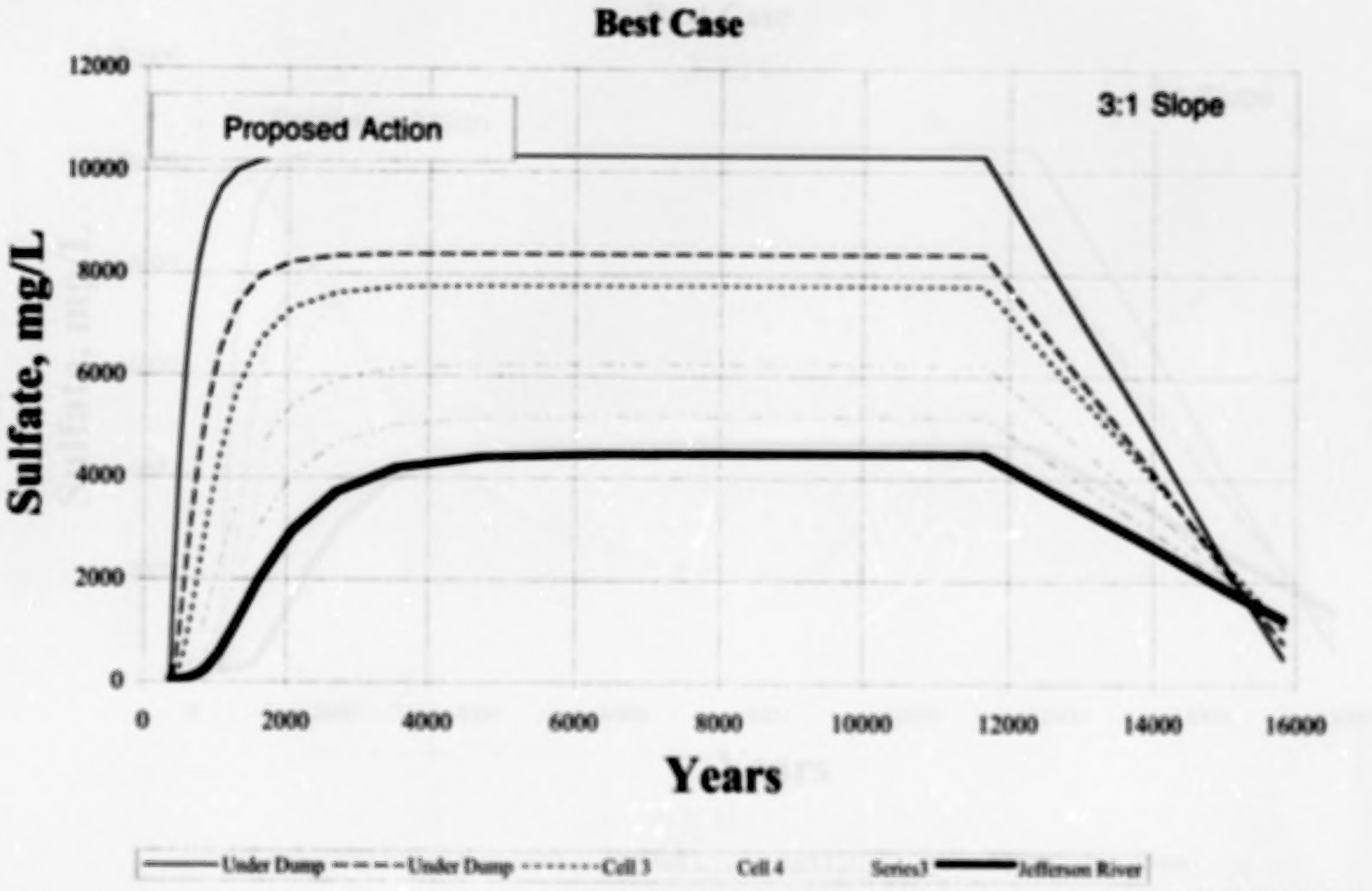

FIGURE J-22 (West Side)

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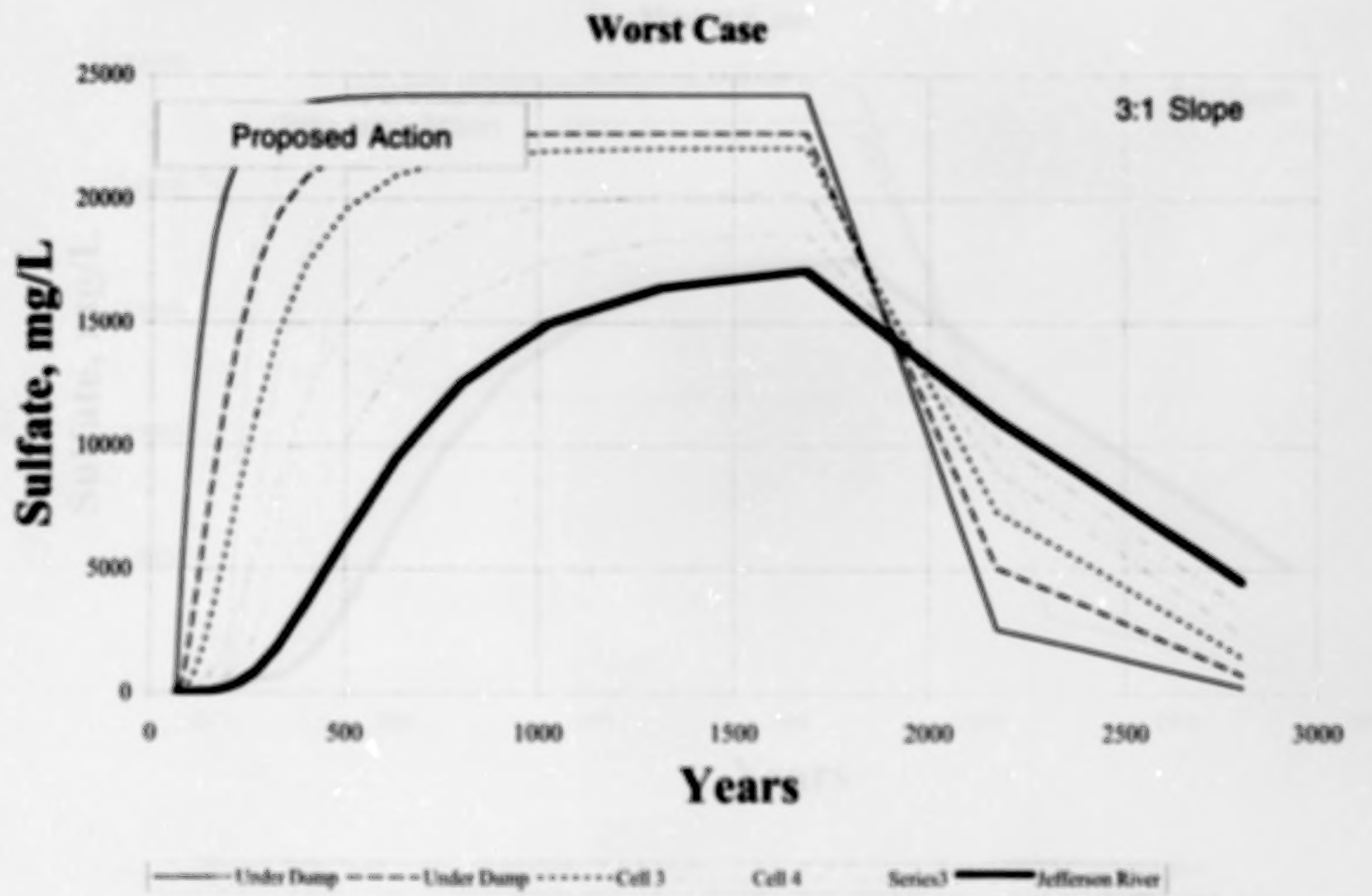

FIGURE J-23 (West Side)

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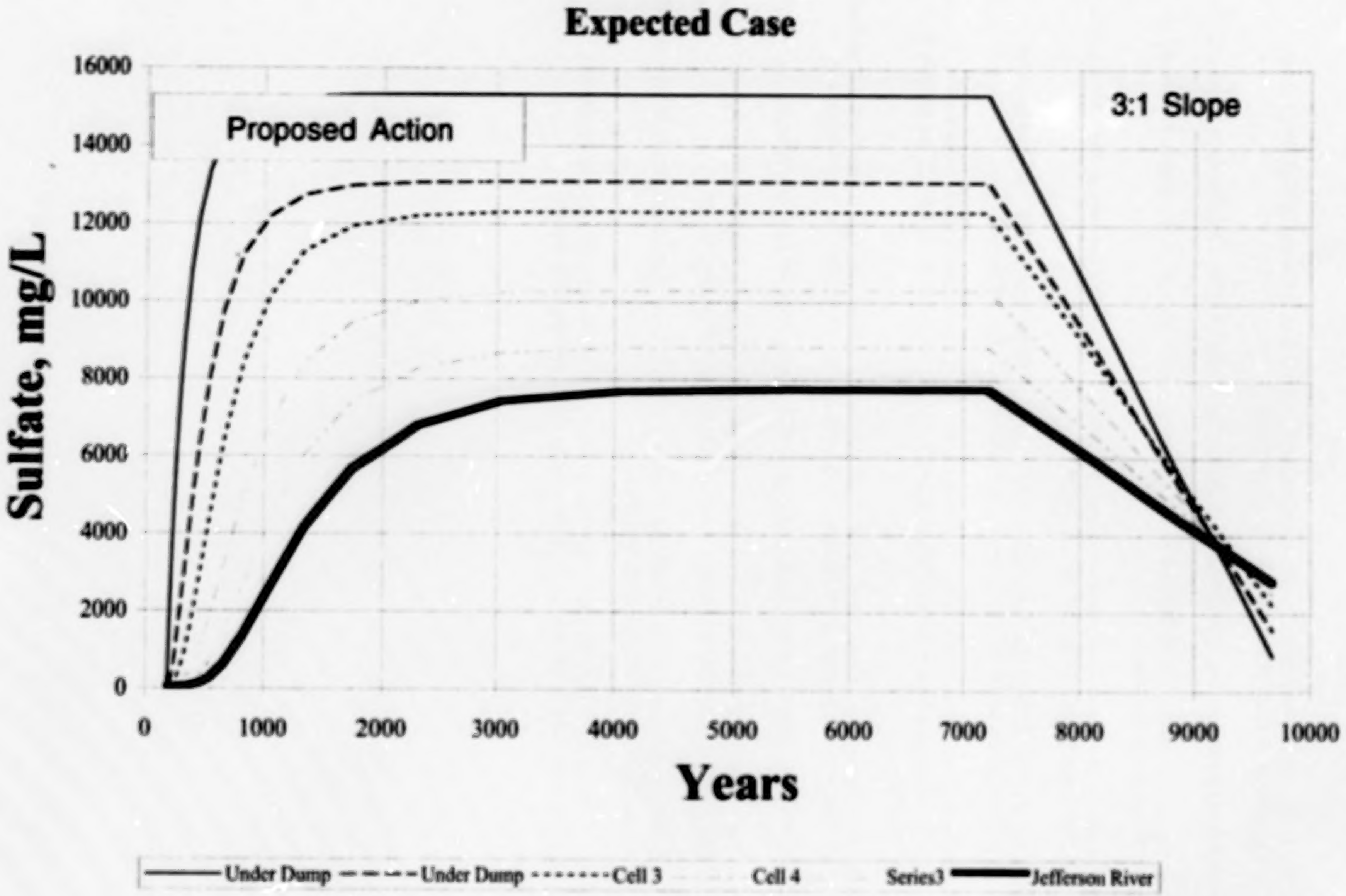

FIGURE J-24 (West Side)

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APPENDIX K

WATER TREATMENT PLANT FAILURE MODES AND EFFECTS ANALYSIS

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APPENDIX K

FAILURE MODES AND EFFECTS ANALYSIS

A Failure Modes and Effects Analysis (FMEA) was performed for the proposed water treatment system for the Golden Sunlight Mines site to determine potential environmental consequences resulting from various system failures. The analysis is based upon information obtained from an August 1996 conceptual design of a water treatment plant for the site. The plant would be used to treat water from the tailings ponds and the open pit mine at the site. The primary components of the system would consist of two cyanide reactors, a neutralization tank, and a clarifier. Sludge produced in the treatment process would be dewatered in a filter press and landfilled on-site, while the treated water would be discharged to a nearby percolation pond. Each of the primary components of the system have been evaluated in consideration of the potential environmental consequences resulting from failure of the component. Table K-1 summarizes considerations made during preparation of the FMEA, including presentation of each failure considered, the resultant effects of the failure, the potential environmental consequences, the likelihood of each failure occurring, and the compensating factors minimizing damage caused by the failure. Also indicated on the table is the confidence level (High, Medium, or Low) given to the prediction of the consequences and likelihoods of each failure. Following are keys explaining the consequence and likelihood categories presented on the table. It should be noted that since the risks are assessed relative to each other, the likelihood of occurrence presented should not be construed in a literal sense, but should be perceived as the likelihood of occurrence relative to the to other failures in the system.

Category	Risk	Environmental Consequence
I	Safe	Negligible
II	Marginal	Failure will cause some environmental degradation, but no major or long-term damage
III	Critical	Failure will degrade environment, and if action is not taken major or permanent damage will occur
IV	Severe	Failure will produce major and irrecoverable environmental damage or severe safety risk

Category	Likelihood of Failure Occurrence
Negligible	less than 1:1,000,000
Very Low	1:1,000,000 to 1:10,000
Low	1:10,000 to 1:100
Moderate	1:100 to 1:10
Significant	greater than 1:10

The following paragraphs provide a brief discussion of the failure considerations. It should be noted that the treatment system would be fully automated and that any system upsets outside of the system control limits would cause the treatment plant to automatically shut down. This feature of the system significantly reduces the likelihood that the failures discussed would result in significant environmental impacts, since for any of the failures presented, failure of the control system would also have to occur for the environmental consequences to take place.

Water from the tailing ponds contains elevated concentrations of cyanide and heavy metals and would undergo treatment for cyanide in the cyanide reactors prior to the addition of the pit water to the treatment process. Cyanide treatment would be performed by raising the pH of the solution with lime addition, which facilitates the oxidation of the cyanide by hydrogen peroxide addition. If the equipment associated with the lime addition failed to inject sufficient amounts of lime, the pH of the water would not be effectively raised. This low pH in the treatment process would reduce the oxidation of the cyanide, hinder the flocculation of the suspended solids, and deter the dissolved metals from coming out of solution. This would result in the discharge of cyanide, suspended solids, and dissolved metals to the percolation ponds and potential groundwater impacts. An additional effect of lime delivery failure may be the production of hydrogen cyanide gas within the plant. This gas could potentially be produced if the untreated cyanide were to come into contact with the acidic pit water (pH = 2.6) in the neutralization tank. Another possible failure associated with the cyanide reactors, would be failure of the hydrogen peroxide delivery system. This failure probably would not cause significant environmental impacts since the majority of the cyanide would likely be precipitated with the metals; however, minor amounts of cyanide could be released to the percolation ponds and groundwater in the event of this type of failure. The potential for a cyanide release is expected to decrease as the cyanide concentrations in the tailings ponds diminish. It is projected that the cyanide concentrations in the tailings ponds will have been reduced to below water quality standards approximately 10 years following start up of the system.

From the cyanide reactors, the tailing ponds water is transferred to the neutralization tank, where pit water would be added to the treatment process. Alkalized sludge and compressed air would also be injected into this solution. Two failures associated with this portion of the process that could cause environmental impact include alkalized sludge delivery failure and compressed air delivery failure. If the alkalized sludge delivery system failed, the pH of the solution would not be effectively raised, likely causing the discharge of suspended solids and dissolved metals to the percolation ponds. Failure of the injection of compressed air into the neutralization tank may prevent the ferrous iron present in the water from being oxidized to ferric iron. Although the ferrous iron would likely precipitate into the sludge, the subsequent landfilling of the sludge may oxidize the iron to ferric iron. This reaction could produce an acidic solution, thereby causing possible mobilization of the metals within the sludge. A failure of this nature would not be expected to result in adverse environmental effects unless it were not remedied within a reasonable amount of time, since the proposed sludge disposal location would be lined. Mixers would be present in the cyanide reactors and the neutralization tank. If the mixers were to fail in either location, it would not be expected that the hydrogen peroxide or lime would be properly distributed throughout the solution. This would may cause improper adjustment to the water and insufficient treatment, resulting in the discharge of sediment, dissolved metals, and cyanide to the percolation ponds.

As the water continues through the treatment process, it enters the clarifiers, where a polymer to induce flocculation is introduced. As the floc settles to the bottom of the clarifier, it is removed and either delivered to a sludge storage tank or recycled back to the alkalization tank for subsequent injection into the treatment process. As the treated water is decanted from the clarifier, sulfuric acid is added to bring the pH of the discharge to between 6 and 9. If polymer flocculent injection into the clarifier were to fail, it would likely result in insufficient settling in the clarifier and the discharge of metal-bearing suspended solids and metals to the percolation ponds and the groundwater. In the event that the sludge removal system were to fail, an accumulation of sludge in the bottom of the clarifier would likely occur, causing a reduction of the residence time in the clarifier and possibly resulting in the discharge of metal-bearing suspended solids or metals to the percolation ponds and potential groundwater impact. In the occurrence of a sludge removal failure, sludge would gather in the bottom of the clarifier. The accumulation of sludge volumes sufficient to disrupt operation of the system would likely take several days or more and would presumably be detected by the system operator before environmental impacts occurred. If the acid injection equipment at the clarifier discharge were to malfunction by injecting too much or too little acid to the decant, the treated water may be released to the percolation ponds at a pH outside of the 6 to 9 range specified for the system. Discharge of water to the percolation ponds with low pH values could result in the mobilization of metals present in the soil and transport them to the groundwater. The discharge of water with a high or low pH could alter the pH of the groundwater if it were prolonged.

Consideration has been made to the consequences of a power failure within the plant. If the flow of impacted water were to continue to the plant in the event of a power failure, the water would travel through the system without the proper treatment and discharge directly to the percolation ponds. In the event of a hydraulic overload, water would pass through the plant with insufficient residence time in each stage of the treatment process. Both of these scenarios would result in the discharge of sediment, dissolved metals, and cyanide to the percolation ponds.

Several of the failure scenarios discussed would result in the discharge of suspended solids, metals, and cyanide to the percolation pond. The severity of the environmental impact from releases of this nature would be entirely dependant on the amount of time that the plant operated under the specified failure. Although the impacted discharge water would be confined to the percolation pond and would not likely be exposed to any other surface water, it would be subject to infiltration and potential exposure to groundwater. To prevent the failures within the treatment system from causing adverse environmental impacts, each of the system components discussed would be monitored by the automated process control software which will be incorporated into the system. This software would interface all automated instrumentation, motors, and valves and would shut down the treatment process in the event of a failure.

Table K-1

Failure Modes and Effects Analysis
Water Treatment System
Golden Sunlight Mines, Inc.

System/Sub-System	Failure Mode	Likelihood of Occurrence		Environmental Effects	Consequence		Compensating Factors
		Category	Confidence		Level	Confidence	
Water Treatment System	Power Failure in Plant	Low	High	Release of sediment, dissolved metals, and CN^- to percolation ponds; groundwater loading	III	High	Automatic Plant Shutdown; Back-up Generations
	Hydraulic Overload	Low	Low	Release of sediment and metals to percolation ponds; groundwater loading	II	High	Automatic Plant Shutdown
Cyanide Reactors	Lime Delivery Failure	Low	Low	a) Release of sediment, dissolved metals, and CN^- to percolation ponds; groundwater loading.	III	High	Automatic Plant Shutdown
		Very Low	Low	b) Potential HCN formation in neutralization tank	IV	Low	Automatic Plant Shutdown
	H_2O_2 Delivery Failure	Low	Low	Release of CN^- to percolation ponds; groundwater loading	II	Medium	Automatic Plant Shutdown

Table K-1 (Continued)

System/Sub-System	Failure Mode	Likelihood of Occurrence		Environmental Effects	Consequence		Compensating Factors
		Category	Confidence		Level	Confidence	
Cyanide Reactors	Mixer Failure	Low	Low	Release of sediment, dissolved metals, and CN^- to percolation ponds; groundwater loading	III	High	Automatic Plant Shutdown
Neutralization Tank	Alkalized Sludge Delivery Failure	Low	Low	Release of sediment, dissolved metals to percolation ponds; groundwater loading	II	High	Automatic Plant Shutdown
	Compressed Air Delivery Failure	Moderate	Low	Release of Ferrous iron in sludge; mobilization of metals in landfill	II	Low	Automatic Plant Shutdown
	Mixer Failure	Low	Low	Release of sediment and dissolved metals to percolation ponds; groundwater loading	III	High	Automatic Plant Shutdown
Clarifier	Polymer Delivery Failure	Low	Low	Release of metal-bearing sediment to percolation ponds	I	High	Automatic Plant Shutdown
	Sludge Removal Failure	Low	Low	Release of sediment and metals to percolation ponds; groundwater loading	II	Low	Automatic Plant Shutdown

Table K-1 (Continued)

System/Sub-System	Failure Mode	Likelihood of Occurrence		Environmental Effects	Consequence		Compensating Factors
		Category	Confidence		Level	Confidence	
Clarifier	Acid Delivery Failure	Low	Low	Release of water with elevated pH to percolation ponds; increase pH of groundwater.	II	High	Automatic Plant Shutdown
	Excess Acid Delivery	Low	Low	Release of water with low pH to percolation ponds; mobilize metals in soil; decrease pH of groundwater.	II	High	Automatic Plant Shutdown

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APPENDIX L

GROUNDWATER CAPTURE SYSTEMS

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Appendix L
Groundwater Capture Systems

1.0 LITERATURE REVIEW

The Proposed Action includes a commitment on the part of GSM to install a groundwater capture system using wells and/or drains, if and when it is determined that groundwater quality has been impacted by acid rock drainage (ARD) from the east or west waste rock dumps. The Proposed Action capture system, as it is currently described in Appendix B, will probably comprise lines of interception wells that would be part of a pump-and treat (PAT) process. Common to all PAT processes are the following components:

- **Extraction** of the contaminated ground water
- **Treatment** of the extracted water
- **Disposal** of contaminants and discharge of the treated water

Since the treatment and disposal components are well developed and have been demonstrated to be technically feasible, the evaluation herein is limited to the extraction component of PAT technology only.

A literature review was conducted to evaluate the effectiveness of groundwater capture systems. The primary method for defining the effectiveness of PAT technology, according to most references, is to evaluate the results of the PAT program with regard to the degree that remediation objectives are achieved. Generally, the EPA mandates remediation objectives be developed in association with remediation goals that are health-risk based, which usually imply the equivalent of aquifer restoration. PAT objectives may include, but are not necessarily limited to: plume containment, contaminant mass reduction, and point-of-use treatment. The basis for employing groundwater extraction technology as a means to achieve remediation goals is founded on two fundamental assumptions (EPA, 1989a):

1) The well system can be designed to produce flow patterns that permit the wells to withdraw all the contaminated water from the aquifer; and
2) The contaminants will be removed from the aquifer with the ground water.

Although much of the available literature relates to PAT effectiveness in aquifers impacted by organic contaminants, many of the factors are also relevant to ground water impacted by metals.
Two important findings of the literature review are as follows:

- It is now generally recognized that properly designed interception-well capture systems can provide ***effective containment*** of most contaminant plumes, thus preventing further migration of contaminants; but

- Groundwater pumping is generally considered ***ineffective for restoring*** aquifers to health-based levels.

These findings represent the conclusions of an evaluation of 16 case studies in a report prepared for the U.S. Department of Energy (Doty and Travis, 1991), and also appear to represent the general consensus of most practitioners and others in the scientific community (see for example the proceedings of the Association of Groundwater Scientists and Engineers, AGWSE, 1992).

In another report of case studies prepared by CH_2M-Hill for the U.S. Environmental Protection Agency (EPA, 1989b), the conclusions were somewhat more optimistic with regard to PAT effectiveness for aquifer restoration. The EPA evaluation utilized information collected for 19 sites where extraction systems were in place and in operation. The conclusions of the evaluation are summarized as follows (EPA, 1989a):

- Groundwater extraction systems are generally effective in maintaining hydraulic containment of contaminant plumes.

- Significant removal of contaminant mass from the subsurface is often achieved by groundwater extraction systems. When site conditions are favorable and the extraction system is properly designed and operated, it may be possible to remediate the aquifer to health-based levels.

- Contaminant concentrations usually decrease most rapidly soon after the initiation of extraction. After this initial reduction, the concentrations often tend to level off, and progress toward complete aquifer restoration is usually slower than expected.

- Data collection, both prior to system design and during operation, was frequently not sufficient to fully assess contaminant movement and the response of the groundwater system to extraction.

Of the 31 case studies reviewed in the DOE and EPA reports, only 2 sites reported complete aquifer restoration, and the validity of those claims has been questioned (Doty and Travis, 1991). So in spite of the optimistic conclusions outlined previously from the EPA report, there appears to be little debate regarding the ineffectiveness of PAT as a means of *restoring* aquifers—at least not to contaminant concentrations developed using health-risk criteria, and not within reasonable time frames. The debate seems to be focused, instead, on the reasons for the ineffectiveness of PAT in meeting restoration goals. This ineffectiveness has been attributed to a variety of factors, including:

- Deficiencies in site characterization;
- Deficiencies in system design;
- Other sources of contamination;
- Hydrogeologic complexities; and
- Contaminant complexities.

Nyer et al. (1996) review the limitations of PAT remediation methods, and discuss how some of the same factors may limit the effectiveness of emerging *in situ* treatment technologies.

Factors of time frame length and operation costs for PAT systems are significant for purposes of evaluating the effectiveness of PAT. The life cycle design of the system must consider both the lifetime of the source, and the microscale aquifer and solute-composition factors that affect the rate of movement of the contaminant plume.

For metals, contaminant-related factors include microscale processes such as retardation and precipitation. Retardation is the result of sorption and ion exchange processes between the metals and the aquifer solids. These processes tend to slow the rate of contaminant migration with respect to the rate that water moves through the aquifer, and act as a mechanism for concentration attenuation. Because of this effect, the plume of a reactive contaminant expands more slowly, and the concentration is less than that of an equivalent non-reactive contaminant. Unfortunately, this retarding effect, while beneficial in the absence of a remedy, increases the cleanup time once the remediation system has been installed. Precipitates in the aquifer solids are another microscale factor that might impact cleanup time. Precipitates tend to act as essentially "limitless" secondary sources of contamination to the ground water. The chemistry in systems containing precipitates may be very complex, and is very difficult to quantify. Dissolution of metals from precipitates during the extraction process may greatly impact the time required to achieve compliance.

Continued leaching from the source areas also must be taken into account when estimating the time that will be required for PAT remediation. When good reclamation and drainage practices have been applied to limit source leaching, the rate of source reduction also is very slow, thus increasing the time to full restoration of the aquifer once the PAT system has been initiated.

The failure or limited effectiveness of PAT with regard to remediating aquifers to risk-based standards in reasonable amounts of time may prove technically infeasible. At the sites reviewed for the EPA and DOE, concentrations of contaminants generally decreased significantly after initiation of extraction, but tended to level off after a period of time. This leveling off usually began to occur at concentrations above the cleanup goals. The objectives for PAT may have to be changed from achieving risk-based standards to achieving plume containment or control. The time period required for plume containment will be site-specific, and should be sufficiently long to achieve contaminant mass reduction that results in reasonably attainable levels of contaminant concentrations. Modification of remedial objectives may be warranted where compliance with cleanup standards is not technically practicable from an engineering perspective.

The key to successful hydraulic containment of a contaminant plume is accurate determination of hydrogeological factors such as: the heterogeneity of the subsurface, the presence of low permeability layers, and the presence of fractures. The aquifer must be sufficiently characterized to design the capture system parameters including: location and spacing of extraction wells, pumping rates, and screen intervals. The hydraulic containment system can be effective only if enough ground water is pumped to intercept the entire plume. Meaningful estimation of flow rates and treatment system design requirements to accommodate highly efficient plume containment requires collaboration of a team of experts (Nyer and Schafer, 1993). Nonetheless, with sufficient site characterization and accurate determination of key hydraulic properties (i.e., transmissivity), highly effective groundwater containment systems are feasible, as has been demonstrated by the numerous documented case histories (EPA, 1989(a) and (b); Doty and Travis, 1991).

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2.0 CONCEPTUAL CAPTURE SYSTEM

2.1 West Waste Rock Dump

2.1.1 Groundwater Conditions

Beneath and adjacent to the West Waste Dump are Precambrian sedimentary rocks and shallow intrusions of Cretaceous latite. The old sedimentary rocks and the latite have very little effective intergranular pore space and transmit water entirely (for practical purposes) through fractures. This fracture flow is thus directed along fracture zones. The groundwater modeling of the pit and surrounding area shows potential groundwater gradients and flow directions, but does not show flow patterns and gradients in detail that may be directed along fracture zones. While this model is a very useful tool to describe overall flow potentials, it has its limitations in capture of contaminant plumes, as indicated below.

Based on available geologic mapping of the bedrock units, faulting and associated veins strike north to northeast. Also, the axes of folds in the sedimentary rocks strike near north. The more permeable fracture zones are assumed to be along these structures. Fracture distribution diagrams are not available to confirm this assumption. Hydrometrics (1995) indicated bulk hydraulic conductivities ranging from 10^{-7} cm/sec to 10^{-5} cm/sec, averaging 10^{-6} cm/sec in their calibrated model. Hydraulic testing in a fault zone in the pit indicated hydraulic conductivities as high as 10^{-4} cm/sec. A variance in hydraulic conductivities of 2 to 3 orders of magnitude can result in concentrated flow in paths along fracture zones.

The above conditions are important to both monitoring groundwater downgradient from the West Dumps and developing a well capture system to intercept groundwater contaminant plumes that may eventually develop. Technically, it is feasible to monitor and intercept groundwater contamination with wells. However, it is critical to the success of a monitoring and interception system that the important fracture zones are identified and penetrated by wells. Otherwise, a single fracture zone, if not penetrated by at least one well, can result in the escape of some contaminant flow depending on the relative hydraulic conductivity of the fracture zone.

Development of both a well interception system and a monitoring well system will require careful exploration to define fracture zones along the down-gradient toe of the west dump. This may require trenching of overburden and detailed mapping of fractures. Surface geophysics would probably be helpful. Mapped fracture zones could then be tested with air down-hole hammer or air rotary drilling by simply recording air-lift pumping rates during and after completion of drilling. For example, Hydrometrics reported that well R17 air lifted 30 gpm whereas well R15 air lifted only 2.0 gpm. Obviously the first test hole penetrated a relatively permeable fracture zone whereas the latter well penetrated a relatively low permeability zone. A drilling approach could be used whereby wells would be drilled on 100-foot spacing and tested by air lift pumping. Based on tests, infill drilling would be used to penetrate fracture zones missed by the 100-foot spacing.

2.1.2 Simulated Groundwater Capture System

A simplified model of the fracture flow system at the West Dump was prepared to simulate flow and to demonstrate the effectiveness of a capture system. The USGS Ground Water flow model MODFLOW was used for the simulations. The model is shown on Figure L-1. The model contains 50 rows and 50 columns of cells with dimensions of 100 feet x 100 feet x 1000 feet (deep). Fracture zones are simulated by five columns (Nos. 5, 15, 25, 35, and 45) each with a hydraulic conductivity of 0.028 ft/day (10^{-5} cm/sec). The remaining cells have hydraulic conductivities of 0.00028 ft/day (10^{-7} cm/sec) which results in an average bulk hydraulic conductivity of 0.0028 ft/ day (10^{-6} cm/sec), which is essentially the same as the model developed by Hydrometrics. Groundwater flux into the fractured flow model is equal to the estimated regional flow. Using a hydraulic gradient of 0.133 and a saturated thickness of 1,000 feet, the flow per 100 feet of width was calculated as q = K (100)(1,000)(0.133). For example, in Figure L-1, groundwater flux into a fracture zone is estimated to be:

$$\begin{aligned} q &= (0.028)(100)(1{,}000)(0.133) \\ &= 1862\text{cfd} \\ &= 9.6\text{ gpm} \end{aligned}$$

The simulated fracture zones represent 10 percent of the cross sectional area of flow, but transmit about 91 percent of the flow under steady state conditions.

As shown on Figure L-2, if a pumping well is placed in each simulated fracture zone (each of 5 columns), and each well pumps 3 gpm, a theoretical capture of 100 percent will result. Capture efficiency was determined by the ratio of flow leaving the groundwater system through the south boundary to the flow entering the groundwater system through the north boundary. If one of the five simulated fracture zones is missed as shown on Figure L-3, theoretical capture efficiency will still be about 94 percent.

Another simulation was conducted to simulate the sensitivity of the capture efficiency to the hydraulic conductivity of the fracture zones. Figure L-4 represents a fracture system where the fracture zones are assumed to have a hydraulic conductivity of 0.28 ft/d (10 - 4 cm/sec). Results of this simulation show that when one fractured zone is missed, the theoretical capture effectiveness drops to 80 percent. Results of these simulations indicate that in a simple fractured flow system a theoretical capture effectiveness of 100 percent is possible when a capture well penetrates each fractured zone. Results also show that missing one fracture zone can significantly reduce capture effectiveness.

2.2 East Waste Rock Dump

2.2.1 Ground Water Conditions

The Tertiary Bozeman Group Sediments (Bozeman Unit) conveys the majority of the ground water from the existing and proposed East Waste Rock area. The unit is believed to be recharged primarily from the bedrock unit and the overlying colluvial/alluvial unit along the east flank of Bull Mountain. The Bozeman Unit is characterized by alternating layers of fluvial clay, silt, sand and fine gravel. The layers are generally discontinuous, although some interconnectivity exists providing permeability to the unit. Hydraulic conductivities in the Bozeman Unit range from 2.5×10^{-5} to 7×10^{-4} cm/sec (Hydrometrics, 1995). Regional groundwater in the Bozeman Unit generally flows to the south and south east. Groundwater flux from the upgradient bedrock aquifer through the Bozeman Unit has been estimated at 1gpm per 100 feet of aquifer (Hydrometrics, 1996). Based on water levels from shallow and deep well pairs, hydraulic gradients in the upper portion of the Bozeman Unit appear to have a significant downward flow component.

The discontinuous nature and spatial variability of the Bozeman Unit in the vicinity of the East Waste Rock Dump produces locally preferential groundwater flow paths. It is important to the success of a monitoring and capture system that the monitor wells and capture wells be placed frequently enough to detect and intercept the preferential flow paths. Because of the significant downward gradient in the vicinity of the East Waste Dump, full penetration of the aquifer with capture wells should be an assumed requirement.

2.2.2 Simulated Groundwater Capture System

In order to evaluate the theoretical effectiveness of a capture system in the Bozeman Unit, a simple model of a homogeneous alluvial flow system was prepared. The USGS ground water flow model MODFLOW was used for the simulations. The model is shown on Figure L-5. The model contains 50 rows and 50 columns of cells with dimensions 10 feet x 10 feet x 181 feet (deep). The upgradient boundary is a constant flux equivalent to the regional ground water flow estimate of 1 gpm per 100 feet of aquifer. The downgradient boundary is simulated as a constant head boundary equal to 181 feet. Boundary conditions on the sides of the model domain are no flow boundaries. The saturated thickness for the flow model (181 feet) was calculated using the regional flux of 1gpm per 100 feet, a hydraulic conductivity of 0.71 ft/d and a hydraulic gradient of 0.15. Hydraulic conductivity for the model shown in Figure L-5 is assumed to be 0.71 ft/d (2.5E-5 cm/s). Figure L-6 shows the potentiometric surface for the above flow system with a well pumping 5 gpm. Results from this simulation indicate a capture effectiveness of 98 percent. This theoretical capture effectiveness in the homogeneous system was achieved with a well spacing of 1 well per 500 feet. To evaluate the effects of heterogeneity on the capture effectiveness, a lower conductivity zone was introduced into the flow model. Figure L-7 shows the flow system with a lower hydraulic conductivity zone. Achieving a capture effectiveness of 98 percent in this model required a well spacing of 1 well per 100 feet with a total withdrawal of 5 gpm. Results are presented in Figure L-8.

These simplified simulations indicate that a high capture effectiveness is theoretically feasible in a heterogenous flow system similar to the Bozeman Unit with a well spacing of 100 feet.

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3.0 PUMPAGE ESTIMATES FOR ALTERNATIVES

3.1 Proposed Action

3.1.1 West Waste Rock Dump

It is assumed the well capture system would be placed along the toe of the West Waste Dump starting at the north end and extending along the west side, the south side and the east side along the Golden Sunlight fault. This configuration is based on the model simulation of pit inflows when the pit pond level reaches elevation 5050 feet. According to this simulation, the cone of depression around the pit intercepts about 20 percent of the baseline ground water flows from the West Dump area. Given the northeast striking faults through the pit with a southeast dip, there is a possibility that significantly more of the West Dump ground water might be intercepted by the pit. This added increment of pit interception would reduce pumping requirements for the well capture system.

A pumping well capture system for the West Dump under this alternative would consist of a line of wells approximately 17,200 feet long. The simulation shown on Figure L-2 indicates that a pumping rate of about 3 gpm per 1000 feet of wells will theoretically result in 100 percent capture, assuming each fracture zone is penetrated by at least one pumping well. Therefore, the estimated pumping rate will be 17.2 x 3 gpm or 52 gpm. If 20 percent (one zone as indicated in Figure L-3) of the assumed fracture zones is missed, a theoretical capture effectiveness of 94 percent will still be attained under these assumptions. However, since the location and spacing of fracture zones is at least partially unknown, an assumed well spacing of 100 feet should be used. With a careful geologic exploration program the well spacing might be extended. The well capture system would not necessarily require pumping of all of the closely spaced wells and many could be abandoned or used as monitoring wells to demonstrate the hydraulic efficiency of the system. The total pumping rate would still be an estimated 52 gpm with most of the pumping from wells penetrating fracture zones.

3.1.2 East Waste Rock Dump

A conceptual pumping well capture system for the East Dump under this alternative would consist of a line of wells about 12,300 feet long. It would extend eastward along the south toe of the east dump and north along the eastern toe of the dump. Using an assumed well spacing of wells on 100 foot centers pumping 1 gpm/100 feet or 10 gpm per 1000 feet, under the Proposed Action the total pumping rate would be: 12,300ft/100 ft x 1gpm = 123 gpm.

This pumping rate may be high and might exceed recharge rates. However these rates may be required to withdraw enough water from storage to achieve desired drawdown and capture. Steady state pumpage required can probably be reduced depending on field conditions.

3.2 Divided Dump Alternative Capture Systems

3.2.1 West Waste Rock Dump

A pumping well capture system for this alternative would consist of a line of wells from 17,200 to 21,500 feet long around the periphery of the West Dump. Only the northeastern side of the dump would require no wells. The pit is a groundwater sink in this area and as in the Proposed Action Alternative, the pit will capture 20 percent or more of ground water beneath the West Dump. It is assumed that wells would be drilled on 100 feet centers and as before, many of these may not be pumped. The pumping rate required for capture would be the same or greater than for the Proposed Action Capture System, or an estimated 52 to 77 gpm, depending on the configuration used for the West Dump.

3.2.2 East Waste Rock Dump

The pumping well capture system for the East Dump under this alternative would be about 23,500 feet long. It would extend along the southern, eastern and northern (in Section 16) margins of the dump. It is more extensive than under the Proposed Action because the East Dump extends to the northeast into another drainage basin. Based on the simulation presented in Figure L-8 total pumpage is equal to 23,500 ft/100 ft x 1 gpm = 235 gpm. This estimated pumpage assumes an alluvial aquifer. Under the Divided Dump alternative, the East Dump may cover areas where limestone exists in the saturated flow system. The presence of limestone may provide neutralization of ARD and consequently pumping requirements may be less than those in the Bozeman unit. As with the bedrock system, well spacing in areas of limestone should be frequent enough detect areas of high conductivity.

3.3 Other Alternatives Capture Systems

Pumpage requirements for the Return Diversion Alternative, the 3:1 Slope Alternative and the No Pit Pond alternative will be generally the same as for the Proposed Action.

4.0 SUMMARY

To evaluate the feasibility of the proposed plan to capture ARD reporting to the saturated flow system below the waste dumps, a conceptual capture system was developed. Hydrogeologic parameters of the GSM site were used in the analysis and simplified flow models were developed for a fracture flow system and heterogeneous alluvial flow system.

Results indicate a high theoretical capture effectiveness is achievable using interception wells. It is critical that the spacing of the interception wells be frequent enough to intercept the preferential flow paths which exist in both the Bull Mountain Bedrock and the Bozeman Unit.

The conceptual capture system was used to estimate the quantity of potential pumpage necessary for a high capture effectiveness. These are:

Proposed Action West Side - 52 gpm
Proposed Action East Side - 133 gpm
Divided Dump West Side - 52 to 77 gpm
Divided Dump East Side - 235 gpm

The concepts examined here show that it is technically feasible to capture contaminant flow using today's technology. By the time groundwater contamination occurs from the waste dumps, there should also be better systems available for interception and treatment.

The results presented in this appendix are theoretical. Concepts used in this analysis should be field tested prior to use as a basis for the design of a capture system.

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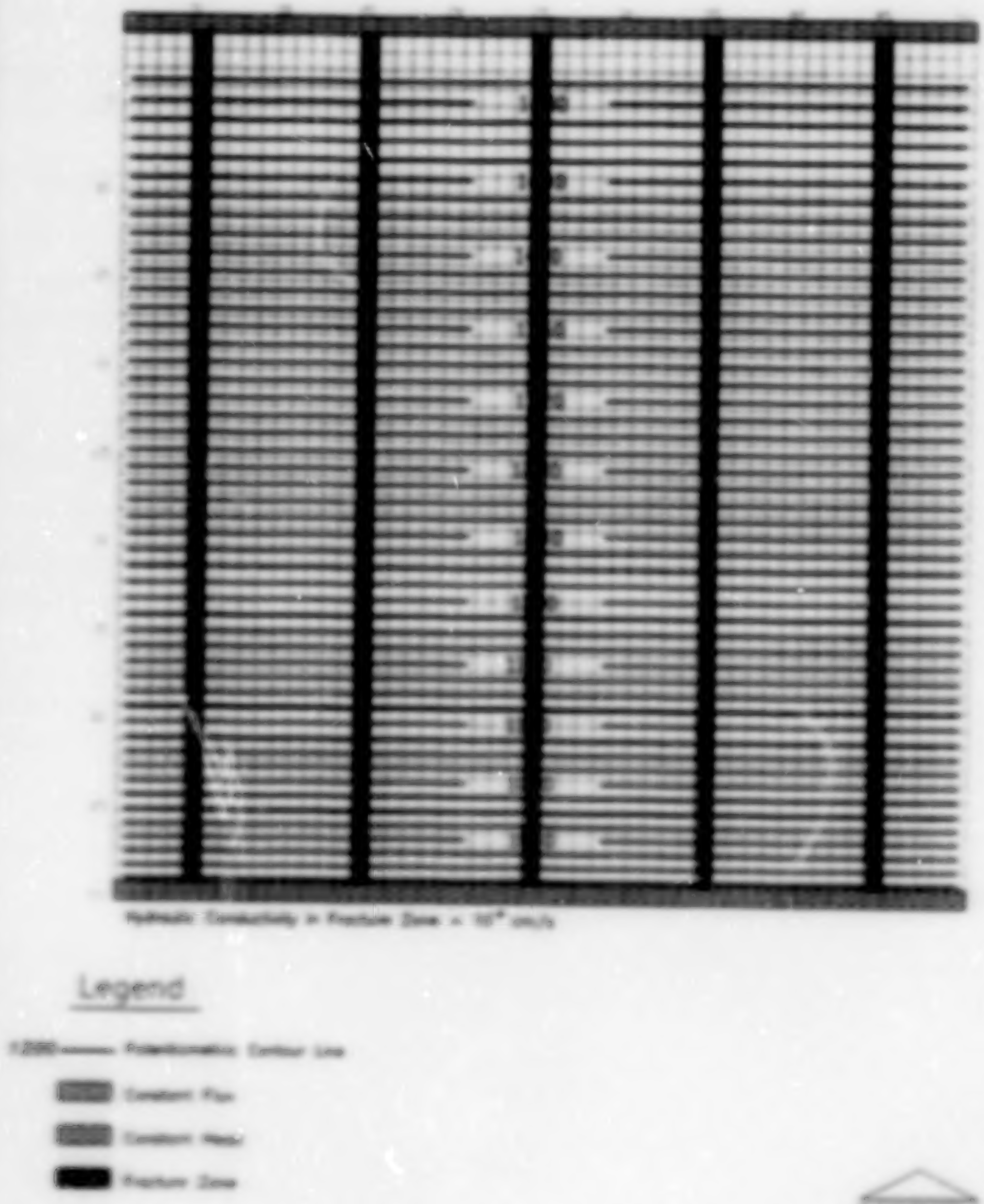
Hydraulic Conductivity in Fracture Zone = 10[illegible] cm/s
Legend
1200 —— Potentiometric Contour Line
Constant Flux
Constant Head
Fracture Zone

GOLDEN SUNLIGHT MINE EXPANSION

FIGURE L-1

SIMPLIFIED FRACTURE FLOW SYSTEM

SOURCE: [illegible]

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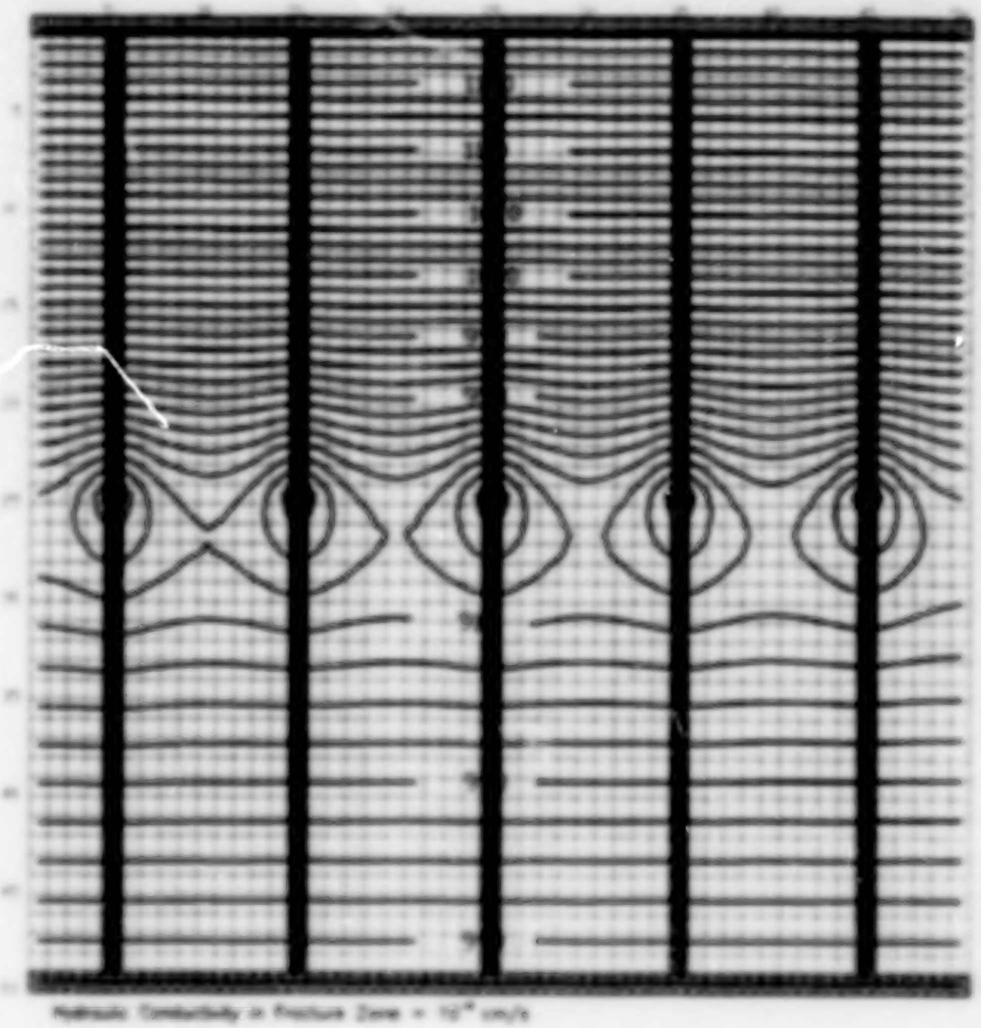

Hydraulic Conductivity in Fracture Zone = 10^{-8} cm/s

Legend

1,000 —— Potentiometric Contour Line

▨ Constant Flux

▨ Constant Head

▬ Fracture Zone

■ Well

NORTH

GOLDEN SUNLIGHT MINE EXPANSION

FIGURE L-2

SIMPLIFIED FRACTURE FLOW SYSTEM
WITH 5 WELLS

SOURCE: [illegible]

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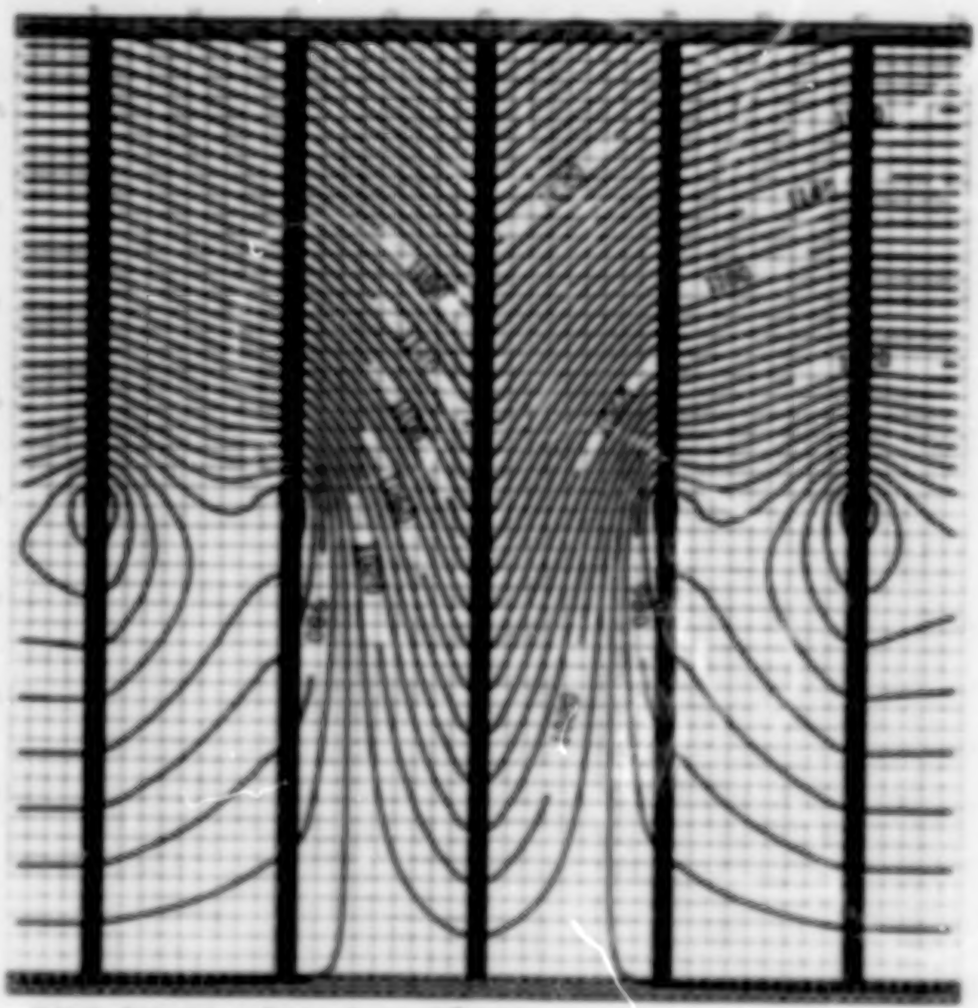
467



Hydraulic Conductivity in Fracture Zone = 10^{-4} cm/s

Legend

1200 —— Potentiometric Contour Line – Ultimate Pit Simulation Under Dewatered Conditions (2006)

▨ Constant Flux

▨ Constant Head

■ Fracture Zone

● Well

GOLDEN SUNLIGHT MINE EXPANSION

FIGURE L-3
SIMPLIFIED FRACTURE FLOW
SYSTEM WITH 4 WELLS

SOURCE: [illegible]

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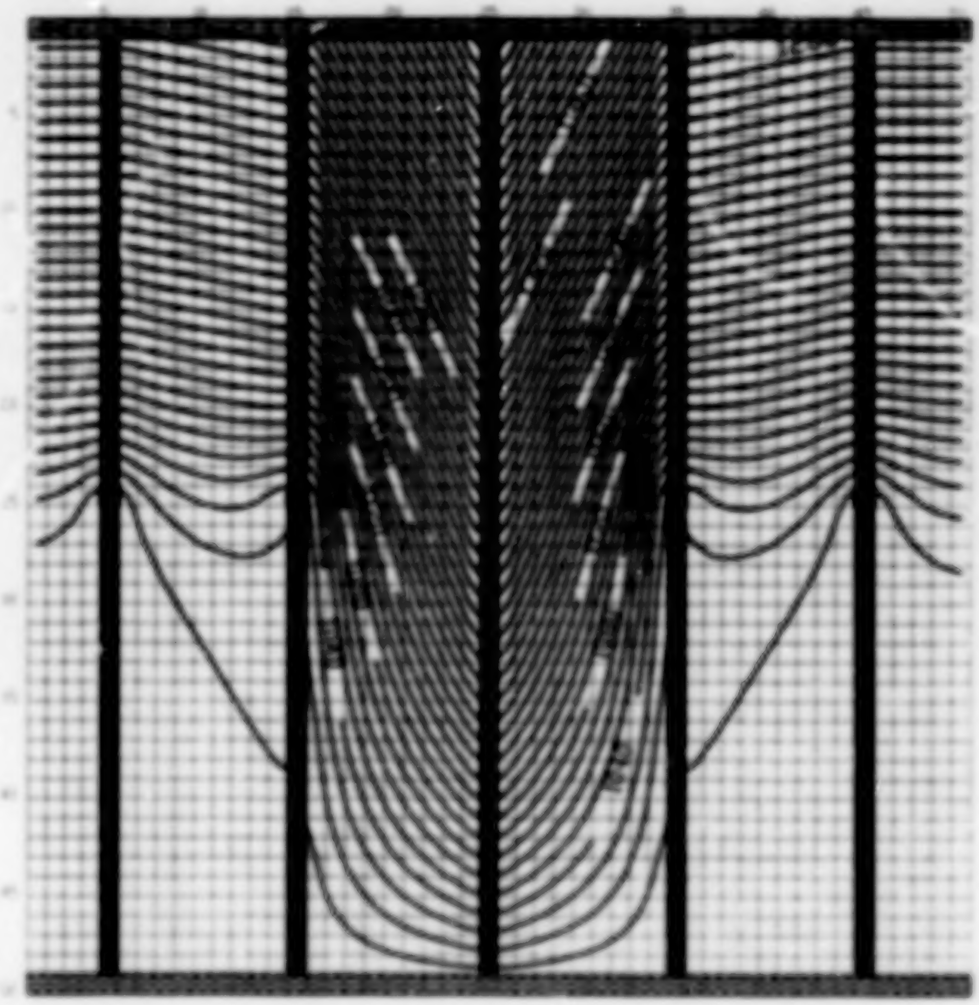

Hydraulic Conductivity in Fracture Zone = 10^{-4} cm/s

Legend

1200 —— Piezometric Contour Line

▨ Constant Flux

▨ Constant Head

■ Fracture Zone

● Well

NORTH

GOLDEN SUNLIGHT MINE EXPANSION

FIGURE L-4

SIMPLIFIED FRACTURE FLOW SYSTEM WITH 4 WELLS

SOURCE: ESA 5-15-87

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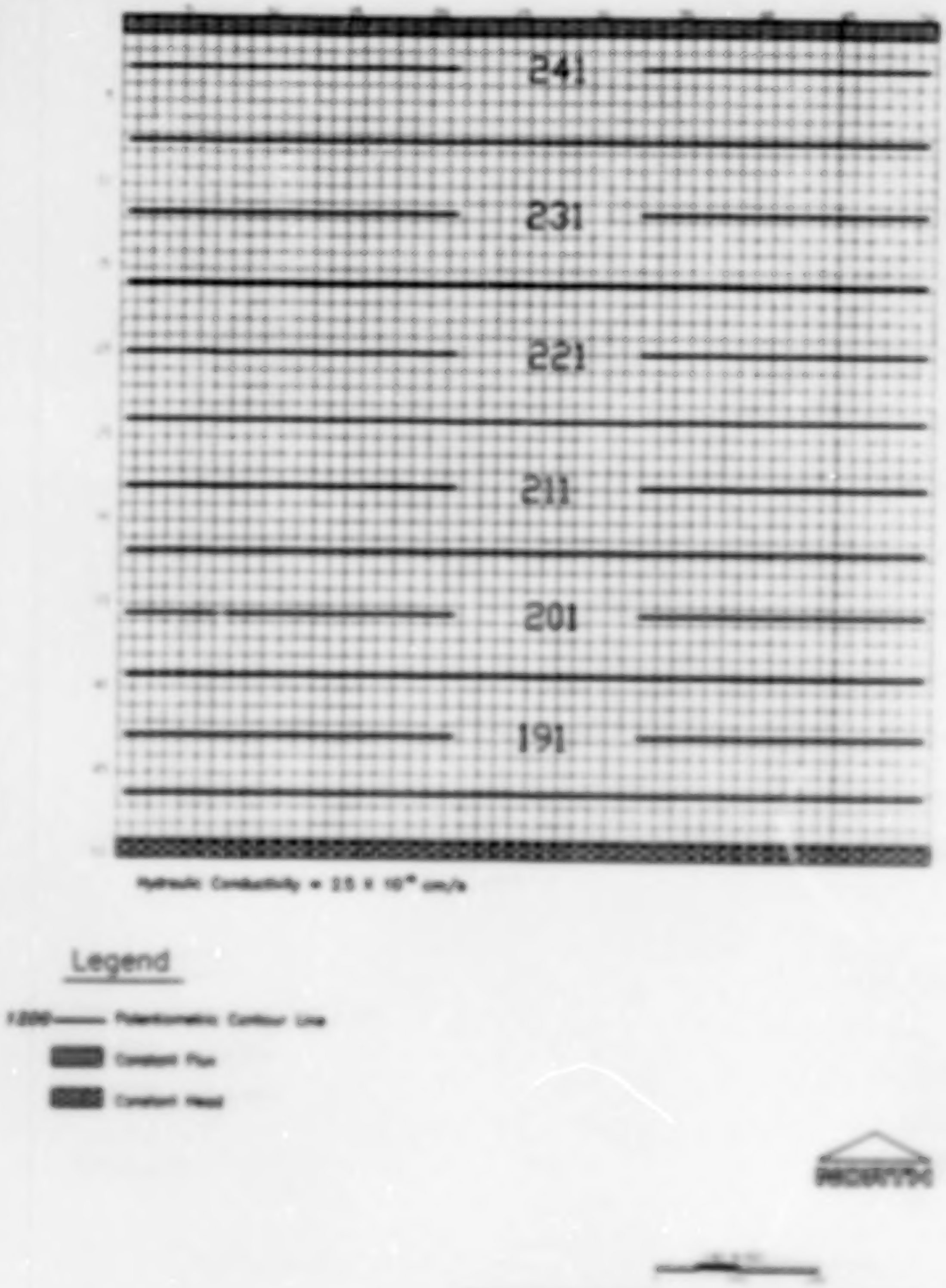
241
231
221
211
201
191
Hydraulic Conductivity = 2.5 x 10[illegible] cm/s
Legend
1200 —— Potentiometric Contour Line
▨ Constant Flux
▨ Constant Head
NORTH

GOLDEN SUNLIGHT MINE EXPANSION

FIGURE L-5
SIMPLE ALLUVIAL
FLOW SYSTEM

SOURCE: ESA 5-13-87

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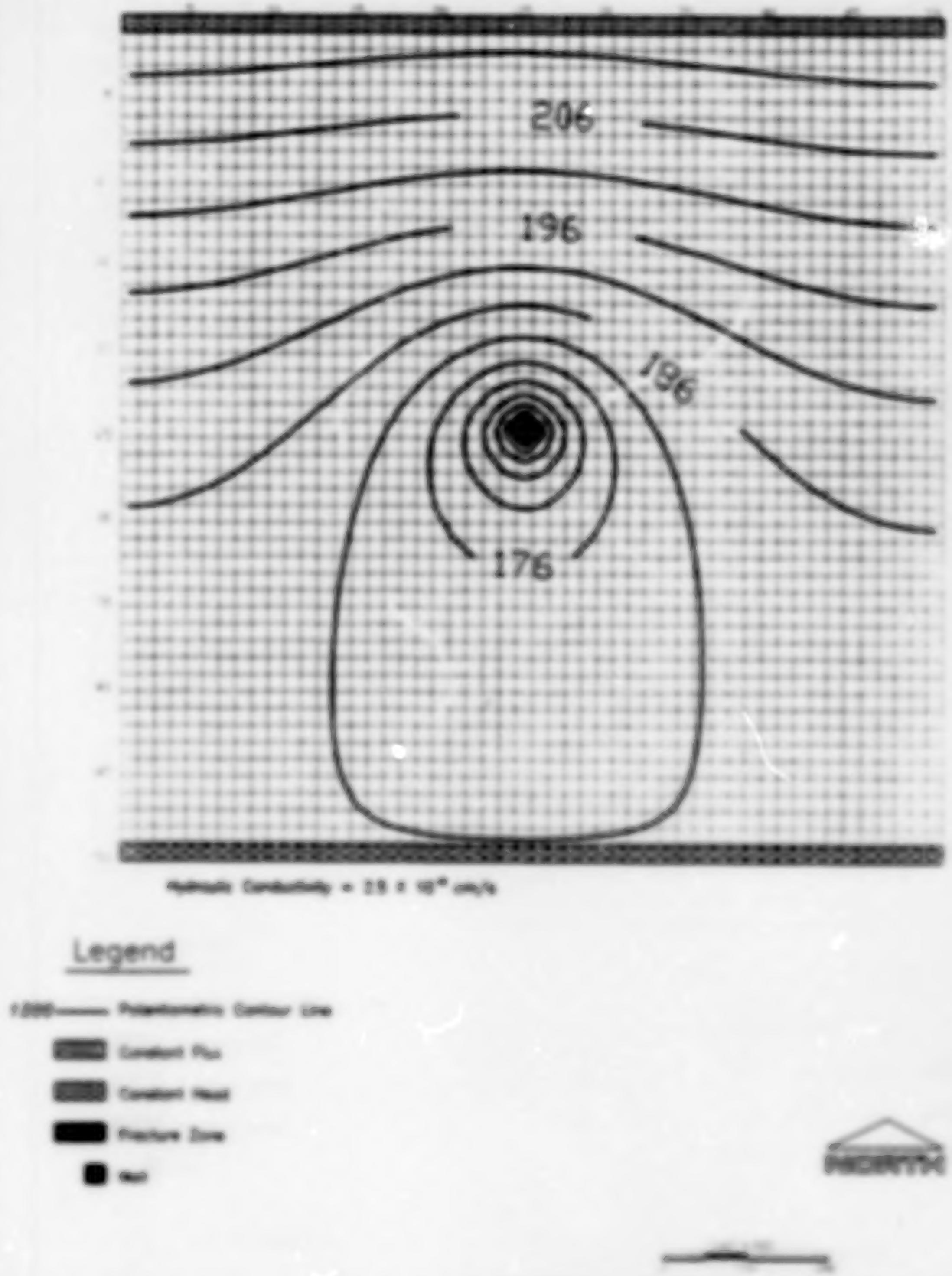
470


206
196
186
176
Hydraulic Conductivity = 2.5 x 10⁻⁴ cm/s
Legend
1200—— Potentiometric Contour Line
▨ Constant Flux
▨ Constant Head
■ Fracture Zone
● Well
NORTH

GOLDEN SUNLIGHT MINE EXPANSION

FIGURE L-6

SIMPLE ALLUVIAL FLOW SYSTEM
WITH ONE WELL

SOURCE: ESA 5-15-87

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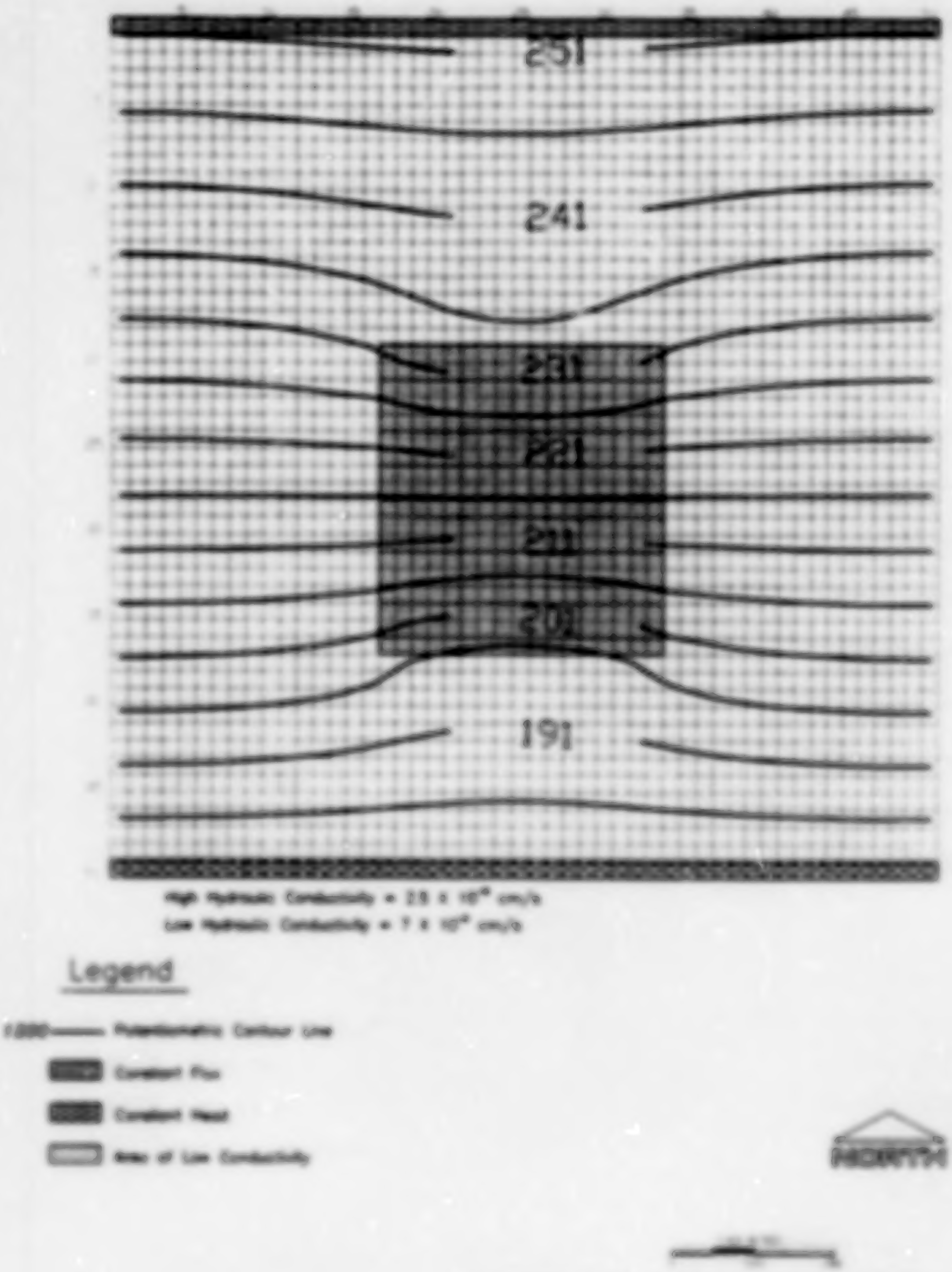

251
241
231
221
211
201
191
High Hydraulic Conductivity = 2.5 x 10[illegible] cm/s
Low Hydraulic Conductivity = 7 x 10[illegible] cm/s
Legend
1000 Potentiometric Contour Line
Constant Flux
Constant Head
Area of Low Conductivity
NORTH

GOLDEN SUNLIGHT MINE EXPANSION

FIGURE L-7
SIMPLE ALLUVIAL FLOW SYSTEM
WITH VARIED HYDRAULIC CONDUCTIVITY

[illegible]

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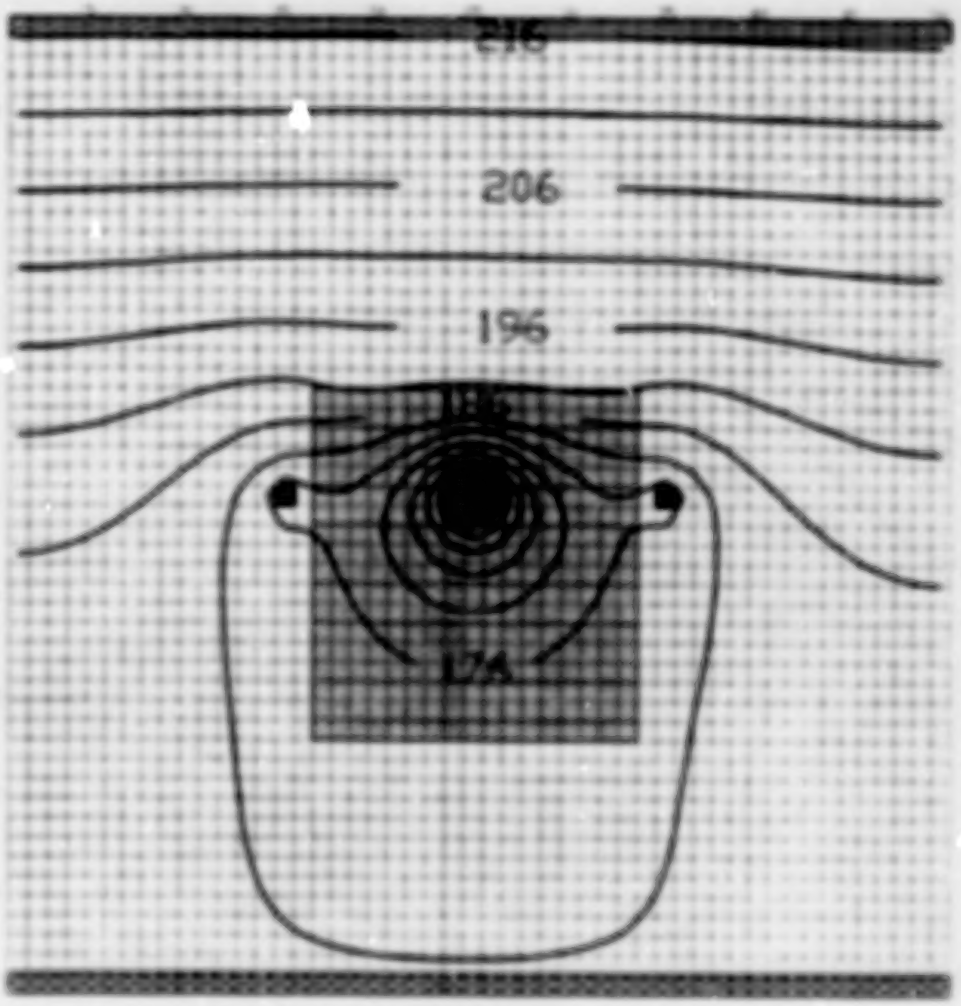

High Hydraulic Conductivity = 3.5 × 10[illegible] cm/s
Low Hydraulic Conductivity = 7 × 10[illegible] cm/s

Legend

1200 —— Potentiometric Contour Line
▨ Constant Flux
▨ Constant Head
▨ Area of Low Conductivity
● Well

NORTH

GOLDEN SUNLIGHT MINE EXPANSION

FIGURE L-8

SIMPLE ALLUVIAL FLOW SYSTEM WITH
VARIED HYRDAULIC CONDUCTIVITY AND 3 WELLS

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APPENDIX M

SOILS - REVISED UNIVERSAL SOIL LOSS EQUATION

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APPENDIX M

To calculate estimated erosion rates for the Golden Sunlight Project, the following assumptions were made for each of the factors used in the Revised Universal Soil Loss Equation (RUSLE). Table M-1, "RUSLE Factors Used to Calculate Current and Potential Erosion Rates, depicts the values assigned for the factors discussed below for each alternative.

Revised Universal Soil Loss Equation (RUSLE) — A (soil loss in tons/acre/year) = RKLSCP, where:

1. Rainfall-runoff factor (R): A value of 15 has been assigned to the project area and was used for all calculations. This value is the same as that used by the MDEQ for the EA previously completed for the project area.

2. Soil erodibility factor (K): The "K" factors used to run the RUSLE equation for the comparisons of erosion on the West Waste Rock Dump are 0.21 and 0.20. These values represent a weighted average of estimated K-factors for the soils to be salvaged and replaced during reclamation on the West Waste Rock Dump facility under two soil salvage regimes. Weighted averages for the soil horizons, as well as the proportion of the total soil salvage volume by soil type, were considered. Coarse fragment percentages of horizons also were taken into account in calculating the K-factor.

3. Slope length and gradient (L/S): The slope gradients selected for reclaimed areas were based on proposed grading plans. Proposed gradients are 2:1 (50 percent) and 3:1 (33 percent). A slope length of 400 horizontal feet was selected for all calculations based on the applicant's proposed plans for constructing benches every 400 horizontal feet down the waste rock dump slope.

4. Cover-management factor (C): This factor was based on the type of vegetation to which the disturbed slopes would be reclaimed, estimated soil roughness factor and other soil conditions, percent bare ground, estimated vegetation canopy cover, height and production, and estimated aboveground plant biomass factors. First and fifth year vegetation cover values used in the equation were based on conservative estimates which were well under the cover values obtained from the test plots on site. This approach was taken since the annual precipitation occurring during the test period was well above the average annual precipitation rate common to the project area.

5. Supporting practices factor (P): Supporting practices are range conservation or surface manipulation techniques which would slow downslope runoff to varying degrees. A value of 1.0 is assigned to smooth, uniform slopes which do not restrict water flow. The value is reduced as surface roughness or slope topographic complexity increases. A value of 0.70 was assigned for the first growing season for both 3:1 and 2:1 slopes given the commitment to surface pitting. Assuming that the effects of surface manipulation techniques would disappear by the fifth growing season, a value of 1.0 was selected for the P-factor for this point in time.

Table B-1

RUSLE Factors Used to Calculate Current and Potential Erosion Rates

Proposed Action	R	K	LS	C		P		Tons of Soil Lost Per Acre	
				Year 1	Year 5	Year 1	Year 5	Year 1	Year 5
Haul Waste from Dump Salvage all soils available (includes all soils regardless of coarse fragment percent)									
2:1 Slopes (400 ft length)	10	0.31	20.1	0.020	0.017	0.75	1.0	1.80	1.20
3:1 Slopes (400 ft length)	10	0.31	17.6	0.013	0.020	0.75	1.0	1.10	0.75
Haul Waste/Rock Dump Salvage all soils with <35% 0.75 inch coarse fragments									
2:1 Slopes (400 ft length)	10	0.20	20.1	0.074	0.074	0.75	1.0	7.20	6.60
3:1 Slopes (400 ft length)	10	0.20	17.6	0.060	0.050	0.75	1.0	4.60	5.60

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APPENDIX N

404(b)(1) COMPLIANCE

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DRAFT SECTION 404(b)(1) EVALUATION

Prepared by

STATE OF MONTANA
DEPARTMENT OF ENVIRONMENTAL QUALITY
and
UNITED STATES
BUREAU OF LAND MANAGEMENT

Prepared for

GOLDEN SUNLIGHT MINES, INC.

November 1997

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DRAFT SECTION 404(b)(1) EVALUATION
Golden Sunlight Mine Expansion and Reclamation Project

1.0 SUBPART A - INTRODUCTION

Golden Sunlight Mine, Inc. (GSM) is presently seeking authorization from COE for placement of fill material in waters of the U.S. (WUS) for the Proposed Action. For purposes of describing the types of potential impacts associated with this activity, a 404(b)(1) showing was prepared for the EIS. This draft section 404(b)(1) evaluation represents an assessment of how the proposed continuance and expansion of mining activities at Golden Sunlight Mine comply with the requirements as set forth in 404(b)(1) guidelines.

Subpart B of the guidelines outlines restrictions imposed on all discharges, the factual determinations required by the guidelines, and specifications for the determination of compliance or noncompliance with the guidelines.

Section 230.10(a) states that no discharge of dredged or fill material shall be permitted, except as provided under Section 404(b)(2) of the Clean Water Act, if there is a practicable alternative to the proposed discharge that would have less adverse impact on the aquatic ecosystem, so long as the alternative does not have other significant adverse environmental consequences.

Section 230.10(b) establishes three conditions, applicable to inland waters, that must be satisfied to make a finding that a proposed discharge complies with the guidelines. No discharge of dredged or fill material shall be permitted if it:

1. Violates applicable state water quality standards;

2. Violates any applicable toxic effluents standard or prohibition under Section 307 of the Clean Water Act; or

3. Jeopardizes the continued existence of species listed as endangered or threatened under the Endangered Species Act of 1973, as amended, or results in likelihood of the destruction or adverse modification of a habitat which is determined to be a critical habitat.

Section 230.10(c) provides that no discharge of dredged or fill material shall be permitted if it will cause or contribute to significant degradation of the WUS, except as provided under Section 404(b)(2). Effects contributing to significant degradation individually or collectively include significantly adverse effects of pollutants on:

1. Human health or welfare, including but not limited to effects on municipal water supplies, plankton, fish, shellfish, wildlife, and special aquatic sites;

2. Life stages of aquatic life and other wildlife dependent on aquatic ecosystems;

3. Aquatic ecosystem diversity, productivity, and stability; or

4. Recreational, aesthetic, and economic values.

Section 230.10(d) prohibits the discharge of dredged or fill material, except as provided under Section 404(b)(2) of the Clean Water Act, unless appropriate and practicable steps have been taken to minimize potential adverse effects of the discharge on the aquatic ecosystem.

Section 230.11 requires the permitting authority to determine in writing the potential short-term and long-term effect of a proposed discharge of dredged or fill material on the physical, chemical, and biological components of the aquatic environment in light of Subparts C to F. Determining the effects of each proposed discharge shall involve consideration of the following:

1. Physical substrate determinations;
2. Water circulation, fluctuation, and salinity determinations;
3. Suspended particulate and turbidity determinations;
4. Contaminant determinations;
5. Aquatic ecosystem and organism determinations;
6. Proposed disposal site determination;
7. Determination of cumulative effects on the aquatic ecosystem; and
8. Determination of secondary effects on the aquatic ecosystem.

Subparts C through F list the potential impacts on the physical and chemical characteristics of the aquatic ecosystem, the potential impacts on the biological characteristics of the aquatic ecosystem, the potential impacts on special aquatic sites, and the potential effects on human use characteristics to be considered in making the factual determinations and the findings of compliance or noncompliance in Subpart B. Subpart G outlines evaluation and testing procedures conducted to obtain the information needed to reach the determinations in Subpart B. Subpart H lists actions to be undertaken to minimize the adverse effects of discharges of dredged or fill material.

This Section 404(b)(1) evaluation includes a description of the proposed discharge of fill material to be evaluated under Section 404 of the Clean Water Act as well as an analysis of the discharge according to the requirements of Subparts B through H. For this evaluation, primary effects are equated with direct impacts, and secondary effects are equated with indirect impacts. Construction-related impacts are considered direct. Indirect impacts can occur at some distance from the project site or can be associated with actions that occur after the project is operational. COE regulations (33CFR 320.4a[2]i-iii) also require consideration of the relative extent of the public and private need, any unresolved conflicts in resource use, and the extent and permanence of the beneficial or detrimental effect of the proposed structure or work on the public and private uses to which the area is suited.

1.1 Project Description

1.1.1 Permitting Background

Operating Permit No. 00065 was granted by the Montana Department of State Lands (MDSL) in 1975 authorizing mining operations at the Golden Sunlight Mine. Amendment 008 was originally approved by the BLM and MDSL in 1990, contingent upon 31 stipulations attached to the Amendment. Table I-1 in the EIS describes the 31 stipulations and the status of GSM's implementation of these requirements. However, legal appeals of the MDSL's approval of Amendment 008 began in September 1990, and culminated in a February 7, 1995, Settlement Agreement requiring an EIS to address possible environmental impacts associated with implementation of Amendment 008. The settlement agreement allows for continued extraction and processing of ore through the completion of this EIS in 1997 or 1998 (the *Interim Dump Plan* period).

GSM is requesting authorization from COE to place fill material in 1.78 acres of non-wetland WUS in conjunction with proposed mine expansion under the Proposed Action. Between 1990 and early 1996, unauthorized fill activities occurred in 0.059 acre of wetland WUS and 2.46 acres of non-wetland WUS. An Administrative Order was issued by EPA which resulted in a Consent Agreement and Order for Compliance, signed August 23, 1996, by GSM and the EPA. The Consent Agreement required implementation of an approved mitigation plan. The COE permitted the "after-the-fact" fill activities under a Nationwide Permit No. 32 in October 1996. A second 404 COE application for 0.62 acre of non-wetland WUS was filed September 23, 1996, for fill activities occurring during completion of this EIS (*Interim Dump Plan* period). This application was approved by COE under Nationwide Permit No. 26 in January 1997. An application for 404 authorization of fill activities under the Proposed Action was submitted to COE in January 1997. Section II.B.2 of the EIS contains a detailed description of the proposed mining operations, environmental protection measures, and reclamation under the Proposed Action.

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1.1.2 The Golden Sunlight Mine Expansion Project

The Golden Sunlight Mine is located on public and private lands in Jefferson County, Montana, approximately 5 miles northeast of Whitehall. The mining operation processes gold-bearing ore using conventional open pit mining techniques. Between 1982 and 1995, approximately 29.0 million tons of ore were processed. An additional 5.1 million tons of ore is expected to be processed through completion of the *Interim Dump Plan*. Total surface disturbance at the end of the *Interim Dump Plan* within the approved permit boundary is 2,336 acres. The proposed expansion would allow for an additional 20.9 million tons of ore to be processed, and increase the total area of disturbance to 2,964 acres.

EIS Section II.B describes alternatives to the Proposed Action. Under the Partial Backfill Alternative, the total area of disturbance would be the same as the Proposed Action. The 3:1 Slope Alternative (Section II.B.5) for reclamation of waste rock dump slopes would disturb up to 3,078 acres within the proposed permit boundary. Where this additional acreage would fill designated WUS, slopes would be graded to the minimum slope between 2:1 and 3:1 to avoid disturbance to WUS. Under the Return Diversion Alternative (Section II.B.3) the ephemeral discharge from Sheep Rock Creek would be routed around the East Waste Rock Dump and back into the channel below the dump. An additional 2.5 acres of surface disturbance would occur for construction of the diversion. Under the Divided Dump Alternative (Section II.B.4), waste rock would be disposed of in one or more of several alternative disposal sites. The East Waste Rock Dump would be divided to avoid permanent placement of fill in the Sheep Rock Creek channel. This alternative would disturb between 2,743 and 2,936 acres.

1.2 Description of Filling Activities Associated with the Golden Sunlight Mine Project

An inventory and delineation of WUS was performed in 1994 (WESTEC et al. 1995) and the results were included in the November 1995 Predischarge Notification (PDN) submitted to the COE. Through completion of the *Interim Dump Plan* (the No Action Alternative), disturbance to 0.059 acre of wetland and 3.08 acres of non-wetland WUS will occur. All disturbance to wetland WUS during previous activities were associated with the burial of seeps at the Midas, North Borrow, Sunlight and Arkose Valley sites. Under the Proposed Action and all other alternatives, no additional disturbance to wetland WUS is anticipated.

To maintain historic flow paths and groundwater recharge associated with the filled seeps, gravel trench systems were constructed over the Arkose Valley and Sunlight seeps. The trenches facilitate continued groundwater movement to eliminate contact with the waste rock pile. Water from the former Midas Spring (approximately 3 gallons per minute [gpm]) is intercepted and conveyed by pipeline to the Golden Sunlight Mine mill facility for use processing ore. Water from the North Borrow Spring (8 to 32 gpm) is intercepted by an underdrain system and conveyed to Tailings Impoundment No. 2.

In general, non-wetland WUS are ephemeral channels flowing only during high intensity thunderstorms a few times each year. These channels convey water from steeper, thin mantled slopes to deeper and more permeable alluvial soils downslope where rapid infiltration and groundwater recharge occurs. These sites provide little to no value as watering holes for wildlife, and with the exception of a few scattered cottonwoods in Sheep Rock Creek, are not comprised of riparian vegetation.

Under the No Action Alternative, no additional acreage or designated WUS would be disturbed other than that already permitted for the *Interim Dump Plan*. The Proposed Action would disturb 1.78 acres of non-wetland WUS and no additional wetland WUS. All alternatives other than the Divided Dump and 3:1 Slope alternatives also would fill 1.78 acres of non-wetland WUS and no additional wetland WUS. The 3:1 Slope Alternative would disturb 2.32 acres of non-wetland WUS. Disturbance under the Divided Dump Alternative would depend on which areas are selected for waste rock disposal, but would generally be less than the Proposed Action. The total WUS disturbance under the Proposed Action, including all past, interim, and proposed activities, would be 4.86 acres of non-wetland WUS and 0.059 acre of wetland WUS.

Storm water flowing in ephemeral draws at the mine is diverted by berms, trenches and swales around mine fill material and back into draws below the fill. Lateral ditches and detention basins promote infiltration of mine runoff. Runoff from the mine site is thereby kept within the basin of origin, and continues to recharge groundwater. In essence, the hydrologic processes which occurred in these drainages prior to development of the mine are maintained by the GSM storm water plan.

Conventional earth-moving equipment, such as front-end loaders, dump trucks, bulldozers, and rubber-tired scrapers, would be used to place fill materials in WUS associated with mine operations.

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2.0 SUBPART B - COMPLIANCE WITH THE GUIDELINES

2.1 Section 230.10 - Restrictions on the Discharge

2.1.1 Section 230.10(a) - Practicable Alternative Analysis

Seven alternatives were developed in response to the environmental issues raised regarding Amendment 008 (Section II.B in the EIS); four alternatives also were examined in less detail (Section II.C). Section III.B.1 describes the surface water resources at and near the Golden Sunlight Mine site, and sub-section III.B.2.d details seeps and springs at the mine, including those impacted through currently permitted mining activities.

The Section 404 program prohibits placement of fill material in designated WUS if there are practicable alternatives that are less damaging to the aquatic environment or if the placement of fill would result in significant degradation of WUS. Because non-wetland WUS would be affected by the proposed mine expansion, the EIS analysis must consider the protection and mitigation of these aquatic resources. Basic information needed to evaluate non-wetland WUS affected by the mine expansion include a characterization, a functional assessment, an impact assessment, and possible mitigation measures. Mitigation requirements are based on acreage, type and the functional quality of the WUS affected by the project. When compensation for functional loss of WUS is required, additional information may be necessary to evaluate whether enhancement, restoration, or creation of compensatory WUS is most appropriate.

The No Action Alternative (Section II.B.1) will result in placement of fill in 3.08 acres of non-wetland WUS and 0.059 acre of wetland WUS. As mentioned in Section 1.1.1, an Administrative Order (the Order) issued by the EPA addressing the "after-the-fact" discharge of fill material into WUS at the Golden Sunlight Mine site from 1990 into early 1996, resulted in a Consent Agreement signed by GSM and EPA in August 1996. The "after-the-fact" period has been permitted by the COE under Nationwide Permit No. 32. A COE 404 permit application for the interim period also has been approved.

For all alternatives, the mining operations, storm water pollution prevention, water quality protection, hazardous materials management, environmental protection measures, and most of the reclamation procedures are identical. Reclamation of the pit under the No Pit Pond (Section II.B.6) and Partial Backfill (Section II.B.7) alternatives differs from reclamation procedures for the pit under the other four alternatives and the No Action Alternative. Reclamation of waste

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rock dumps and tailings impoundments under the Proposed Action differs slightly from that approved under the *Interim Dump Plan*.

The proposed mine expansion or Proposed Action Alternative allows for continued operation of the mine through 2006 and would result in an additional 1.78 acres of discharge of fill material into non-wetland WUS. This alternative proposes routing any flow in Sheep Rock Creek to the northeast, into a tributary to Conrow Creek.

The Return Diversion Alternative (Section II.B.3) addresses concerns over diverting water from Sheep Rock Creek out of the basin of origin under the Proposed Action. An additional 2.5 acres of on-site disturbance would occur to accommodate construction of a diversion channel around the East Waste Rock Dump. The channel would convey discharge in Sheep Rock Creek from a diversion structure upstream of the dump, around the dump, and to a discharge point in a tributary swale of Sheep Rock Creek. This alternative also would result in the discharge of fill material into 1.78 acres of non-wetland WUS (same as Proposed Action).

The 3:1 Slope Alternative (Section II.B.5) proposes 3:1 final slope grades on the East, South, and West Waste Rock Dumps prior to revegetation. Relative to the Proposed Action, reducing waste rock dump slopes would disturb at most an additional 114 acres. However, to avoid additional discharge into WUS, the alternative allows for slope increases to between 3:1 and 2:1 where additional WUS may be affected.

The Divided Dump Alternative (Section II.B.4) addresses concerns about fill material being placed directly into Sheep Rock Creek. The total acreage of WUS affected would depend on the acres selected for waste rock disposal. The acreage disturbed by specific areas is shown in Table N-1. A maximum and minimum scenario have been developed to describe a range of potential surface area disturbance. The maximum scenario would involve utilization of Areas A, B2, and the land bridge (total of 0.94 acre of WUS disturbed). The minimum scenario would involve utilization of Area C2 only (total of 0.71 acre of WUS disturbed). The agencies may select a combination of one or more of the waste rock disposal areas, in whole or in part; therefore, the actual WUS disturbed could be greater or less than that estimated for the minimum and maximum scenarios. Transportation requirements for loaders moving material east across Sheep Rock Creek, buttressing of expanded dump facilities east of Sheep Rock Creek, and altered phasing of mine and land stripping operations would require that 1,750 feet of 2,500 feet of WUS within Sheep Rock Creek be temporarily disturbed.

As mentioned above, in the No Pit Pond (Section II.B.6) and Partial Backfill (Section II.B.7) alternatives differ from the Proposed Action only in the reclamation of the open pit. No change in discharge to WUS under these alternatives is anticipated.

Table N-1

Disturbance to WUS from Waste Rock Areas Under the Divided Dump Alternative

Area Abbreviation	Net WUS Acreage (acres)*
B1	1.08
B2	0.54
Land-Bridge	0.40
A	0.00
C2	0.71
C1	0.77
C1 Haul Road	0.05
TOTAL	3.55

*Includes buffer areas.

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Four alternatives were developed to address environmental concerns (Section II.C) but were not analyzed in detail in the EIS. None of these alternatives differed from the Proposed Action in the amount of non-wetland WUS subject to discharge of fill from mining operations. Engineering, environmental, and economic factors were considered when deciding whether further analysis of an alternative was necessary. In each case, alternatives described in Section II.B were able to provide as good or better assurances against environmental degradation subject to the constraints imposed by engineering and economic criteria.

The Overdrain Alternative (Section II.C.1) addresses the same concern as the Return Diversion Alternative described above but would result in additional water quality concerns that would not occur with the Return Diversion Alternative. The Cyanide Neutralization Alternative (Section II.C.2) addresses the potential for wildlife exposure to cyanide in the tailings impoundments, which is being remedied by installation of the INCO/SO_2 process and the wildlife hazing program described in Section II.B.1. The Acid Neutralization Alternative (Section II.C.3) was formulated to address the need for long-term treatment of acid rock drainage (ARD) from Tailings Impoundment No. 2 after mine closure; however, there is no indication that ARD would be a problem at Tailings Impoundment No. 2, and GSM has measures to treat any that might be formed. The Complete Backfill Alternative (Section II.C.4) would require backfilling of the pit with waste rock to restore pre-mining contours. The costs of this alternative would be prohibitive (see Appendix D, Economic Analysis for Pit Backfilling).

2.1.2 Section 230.10(b) - Discharge Compliance with Guidelines

The Section 404(b)(1) guidelines Section 230.10(b) require that no discharge shall be authorized if it:

1. Causes or contributes to any violation of applicable water quality standards;

2. Violates any applicable toxic effluent standard or prohibition under Section 307 of the Clean Water Act; or

3. Jeopardizes the continued existence of species listed as threatened or endangered under the Endangered Species Act (ESA) of 1973, as amended, or results in the increased likelihood of destruction or adverse modification of critical habitat under the ESA.

Placement of fill materials in wetland and non-wetland WUS during the operation, expansion and reclamation of the Golden Sunlight Mine has been evaluated under the following:

State water quality standards - The Montana Department of Environmental Quality (MDEQ) provides Section 401 Water Quality Certification pursuant to state rules (Administrative Rules of Montana [ARM] 16.20.1701 et seq.). The MDEQ review will indicate whether or not the proposed placement of fill material is in violation of applicable state water quality standards. Any conditions of the state 401 certification will be included as conditions of the Section 404 permit. Section 401 certification does not constitute a relinquishment of MDEQ's authority or any subsequent alterations or additions thereto, and it does not fulfill or waive any other local, state, or federal regulations.

Toxic effluent standard or prohibition - Section 307 of the Clean Water Act requires that the project be reviewed for its potential to introduce toxic pollutants into WUS. Documentation of the potential for ARD from fill materials resulting from this project is contained in the EIS. Determination of compliance with Section 307 will be covered under the MDEQ review. As indicated above, Water Quality Certification pursuant to Section 401 of the Clean Water Act will be required. All conditions identified in the Section 401 certification will be included as conditions if the 404(b)(1) evaluation results in a recommendation to issue a permit.

Threatened and Endangered Species - Impacts to threatened or endangered species are addressed in the EIS (Section IV.F) and in Section 4.1 of this evaluation. To comply with ESA requirements, a Biological Assessment (Appendix E) was prepared to evaluate the potential effects on threatened and endangered species which may be present in the project area. GSM must successfully meet these requirements in order for the 404(b)(1) evaluation to result in a recommendation to issue a permit. The applicant realizes that failure to meet the requirements of this section will result in a recommendation of denial.

Findings related to water quality standards, toxic effluent standards and threatened and endangered species are discussed below.

Water quality findings - Section III.B of the EIS summarizes surface water and groundwater resources of concern at the Golden Sunlight Mine site, and includes water quality descriptions of the various features at the mine. Major findings are as follows:

1. Surface water quality downgradient from the mine in Jefferson Slough has roughly neutral pH, low metal concentrations, and low total dissolved solids (TDS). Cyanide has been sporadically detected but detections are believed in error because duplicate or subsequent samples have been below detection limits.

2. Storm water quality is managed by routing water away from areas which could potentially generate ARD, and encouraging infiltration and recharge where appropriate. GSM's Storm

Water Pollution Prevention Plan (SWPPP) filed with MDEQ in August of 1995 specifies these pollution prevention measures.

3. Groundwater quality is highly variable at the Golden Sunlight Mine site. Groundwater is routinely monitored for signs of off-site migration of ARD or cyanide. Measures to protect groundwater are presented in EIS Appendix A and Section IV.P, Mitigation and Monitoring.

4. Pit water has low pH, high TDS and high concentrations of dissolved metals. This water is collected in a sump within the pit and used in the ore processing facility.

5. An incident of cyanide contamination of groundwater occurred in the early 1980s due to a construction defect in a slurry cut-off wall at Tailings Impoundment No. 1. Prompt action was taken to repair the wall and minimize further downgradient migration, and a voluntary monitoring program was established for private citizens whose wells may have been affected by the breach from the impoundment. Since 1994, all wells where cyanide had been detected have been below detection limits. Further migration of contaminated water from Tailings Impoundment No. 1 has been minimized by a series of pump back wells established on the eastern and southern flanks of the impoundments.

6. Cyanide leaching from Tailings Impoundment No. 2 is not likely due to a 60 mil high density polyethylene (HDPE) liner, impoundment drains, and seepage/reclaim basins. Water from the impoundment drains entering the reclaim basins is either used for processing ore or pumped back into the impoundment. In addition, GSM is initiating an INCO/SO_2 process in 1997 to reduce cyanide in the impoundment.

Fill discharged into designated WUS is described in Section 2.2.1 of this appendix. Routing water around fill areas minimizes the potential for ARD to be produced. Rock drains and gravel trenches beneath previously filled seepage areas maintains groundwater flow such that the pre-mine recharge function of these seeps is maintained.

Toxic effluent findings - Based on geochemical testing and the acid generating character of the sulfide minerals prevalent at the site, there is the potential for toxic effluents to be generated from materials placed in non-wetland WUS from the expansion proposal. The following summarizes findings in Section II.B of the EIS:

1. Water quality from the seeps within the mine site reflects the sulfide-bearing substrate which characterizes the site. Seep water typically has low pH, high concentrations of dissolved metals, and high TDS. Historical accumulations of iron-oxides suggests that ARD is produced naturally.

2. ARD is generated from groundwater inflows and precipitation that contacts acid-producing rock in the pit. A slowly migrating wetting front is moving downward within the waste rock dumps, but there is no indication that leaching of ARD below the dumps has occurred. The tailings impoundments contain water with cyanide concentrations above receiving water standards and will eventually produce ARD.

3. Certain rock types within the area and excavated from the pit have high net acid production potential and are excluded from use as fill material for WUS, drain material, or cap rock for reclamation purposes. These are either processed as gold-bearing ores, or disposed of in a waste rock dump.

Threatened and endangered species findings. Information regarding federally listed threatened and endangered species findings is presented in Section IV.F of the EIS. The Biological Assessment can be found in Appendix E. The analysis identified five federally listed species, two federal candidate species, and five BLM sensitive species (formerly classified by te USFWS as candidate-category 2 species) potentially occuring in the mine vicinity. None of these are aquatic species. None of the species identified would be affected by the proposed fill of 1.78 acres of WUS. Impacts associated with other proposed mining activities are addressed in mitigation measures described in EIS Section IV.P.5.

2.1.3 Section 230.10(c) - Degradation of Waters of the U.S.

Section 230.10(c) guidelines prohibit the discharge of dredge or fill material that will cause or contribute to significant degradation of WUS. Findings of significant degradation must be based on factual determinations, evaluations, and testing. Section 230.10(c) provides that no discharge of dredged or fill material is permitted if it will cause or contribute to significant degradation of WUS, except as provided under Section 404(b)(2). Effects contributing to significant degradation individually or collectively include significant adverse effects of pollutants on the following:

1. Human health or welfare, including but not limited to effects on municipal water supplies, plankton, fish, shellfish, wildlife, and special aquatic sites;

2. Life stages of aquatic life and other wildlife dependent on aquatic ecosystems;

3. Aquatic ecosystem diversity, productivity, and stability; and

4. Recreational, aesthetic, and economic values.

Adverse effects of pollutant discharge on human health as itemized in (1) above are considered minimal due to the small acreage (1.78 acres) and relatively low value of the non-wetland waters under consideration. The ephemeral draws at Golden Sunlight Mine convey storm water from high intensity storms downslope for rapid infiltration and recharge of groundwater. Though the routing of this storm water will be altered due to the proposal, the primary function of groundwater recharge will not be impaired. In addition, there are no fisheries or supporting aquatic ecosystems which will be affected by the proposal.

There is potential for leaching from the tailings impoundments into groundwater upgradient from Jefferson Slough or private wells in the area. Contamination did occur in the early 1980s due to a breach of a slurry wall at Tailings Impoundment No. 1 (Section 2.1.2), but remediation was prompt and effective. The pollution prevention measures described previously and improved technology at the active impoundment (Tailings Impoundment No. 2) should ensure that threats to human health and welfare, including those to wildlife productivity and diversity, are minimized.

Adverse effects of the pollutants on recreational, aesthetic, and economic values is considered low. Access to the mine site has been restricted since the Operating Permit was granted in 1975, and no significant differences in operating procedures at the mine are anticipated from the proposed expansion. GSM has mitigated recreation losses by purchasing private lands and allowing public recreational use and enhancing wildlife habitat. Reclamation of the mine following closure will re-establish wildlife use of the area and partially restore the hunting value of the site.

2.1.4 Section 230.10(d) - Appropriate and Practicable Steps to Minimize Potential Adverse Impacts of the Discharges on the Aquatic Ecosystem

The two primary steps taken at Golden Sunlight Mine to minimize adverse impacts to designated WUS are siting of mine features and facilities to minimize disturbance to WUS, and water quality protection measures as previously described. All alternatives described in Section II.B of the EIS were evaluated in detail with respect to environmental, engineering and economic criteria. The alternatives discussed in Section II.C were eliminated earlier in the evaluation process because they were not able to optimize between these criteria as effectively as the alternatives analyzed in detail.

All alternatives discussed in Section II.B include water quality protection measures designed to minimize hydrologic exchange between waters originating on disturbed areas of the mine with water flowing naturally in surface drainages or as groundwater. GSM's proposed Water Management Plan is presented in EIS Appendix A. Protection measures for surface water include the routing and conveyance of storm water in ephemeral draws around surface

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impoundments and waste rock piles, and capture and use or treatment of precipitation falling directly on impoundments or waste rock. All surface water accumulating within the pit is pumped out of the pit for reuse in processing ore.

Differences in the siting of facilities and mine features are largest between the No Action Alternative and the other six alternatives. The No Action Alternative would disturb 3.08 acres of non-wetland WUS and 0.059 acre of wetland WUS. With the exception of the Divided Dump and 3:1 Slope Alternative, all alternatives including the Proposed Action would disturb an additional 1.78 acres of non-wetland WUS. The Divided Dump Alternative would maintain Sheep Rock Creek in its original channel, and would disturb less WUS than the Proposed Action.

Mitigation - Wetland and Non-Wetland Waters of the U.S. As previously mentioned, project impacts to wetland and non-wetland WUS from "after-the-fact" fill activities are addressed by the Consent Agreement signed by GSM and the EPA. The Consent Agreement requires approval and implementation of a mitigation plan for impacts to WUS due to prior fills. The "after-the-fact" fills are authorized under COE Nationwide Permit No. 32. COE issued a Nationwide Permit No. 26 to GSM for fill activities occurring during the *Interim Dump Plan* (0.62 acre). GSM has applied for an additional COE permit for the Proposed Action. Appropriate and practicable steps to minimize additional disturbance to WUS and protect water quality have been addressed here and in the EIS. Implementation of the mitigation plan is underway.

GSM's Water Management Plan is presented in EIS Appendix A. Measures contained in the plan focus on maintaining natural pathways for surface and groundwater not exposed to mine contaminants, and on minimizing exchange between water that has contacted potentially contaminating materials and natural surface or groundwater.

On-site mitigation for fill discharged into wetland and non-wetland WUS has been ongoing since 1982. Mitigation measures enacted to protect and enhance wildlife resources within the 5,071-acre Golden Sunlight Mine permit boundary include:

1. Seasonal and areal restrictions on cattle grazing to increase forage for mule deer;
2. Creation of a wildlife watering system; and
3. Reclamation of disturbed sites using predominantly native grasses and shrubs.

Off-site mitigation also has been ongoing since 1982, when a 1.7-acre gravel quarry pond was reclaimed for wildlife use. The pond includes an island for nesting waterfowl, and a wetland fringe of approximately 0.01 acre.

In 1989, GSM purchased 3,200 acres of deeded land and leased 1,900 acres of state and federal lands encompassing existing wetlands that had been functionally degraded by heavy livestock use. GSM has limited livestock use of the site, and wetland vegetation in this area has increased from 0.01 acre in 1989 to between 0.05 and 0.1 acre since land use controls were initiated. Additional fencing of seeps and wet meadows on this land will occur, with further development of the existing springs at two sites to maximize wetland rejuvenation and expansion. Enhancement of these seeps will provide a more dependable supply of water for wildlife and expand wetland habitat. Wildlife utilization of the area is expected to increase in response to these enhancements.

The springs will be developed by constructing a groundwater collection and diversion system at each site. The depth of the excavation for collection of groundwater is site specific, but should vary between 2 and 6 feet and extend from 4 to 10 feet from the source. Each collection basin will be filled with gravel, and a small, HDPE lined dam will be located a few feet beyond each spring source. Water will back up behind each dam and will be routed through an overflow channel into adjacent wetland areas. The existing wetland areas and buffer zone will be fenced to exclude livestock but will allow wildlife access.

In addition to the wetland enhancement measures, approximately 26 acres of riparian and upland areas along the Jefferson Slough were fenced by GSM to exclude livestock use and enhance existing streambank areas. In 1991, GSM also began fencing of approximately 120 acres of existing riparian and wetland area along North Boulder River to exclude livestock and protect the streambank from further damage.

In 1991, GSM purchased the 531 acre Piedmont Swamp southwest of Whitehall. A recent survey by the Montana Natural Heritage Program documented a new addition to state flora (a federally listed threatened species) and two plant species of special concern. GSM is being assisted by Ducks Unlimited; U.S. Fish and Wildlife Service; NRCS; BLM; Montana Department of Fish, Wildlife, and Parks; and the Skyline Sportsmen Association to develop a management plan for this area. This plan will preserve this wetland for its biodiversity and habitat values.

2.2 Section 230.11 - Factual Determinations

The potential adverse impacts of placing fill material on the physical, chemical, and biological components of ecosystems of wetland and non-wetland WUS have been evaluated. Mitigation efforts to offset adverse impacts also have been considered for impacts to wetland and non-wetland WUS filled by mining operations. Determination of these impacts are discussed in the following subsections.

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2.2.1 Section 230.11(a) - Physical Substrate Determinations

Materials used for fill at Golden Sunlight Mine consist of four types:

1. Native materials of chemically non-reactive soils are obtained from local borrow pits and used for all road construction crossing WUS. These materials also were used for construction in the general area of the mill and support facility complex, and for wing-dams along the main embankments of the tailings impoundments.

2. Waste rock from the open pit contains sulfide minerals with potential to produce ARD. As mentioned previously in this appendix, GSM's water management program maintains hydrologic isolation of waste rock deposited in dumps by diverting run-on water, containing run-off from waste rock dumps with retention berms, and reclamation to minimize formation of ARD.

3. Engineered drainage materials placed in WUS include coarse river rock and gravel, PVC and HDPE pipes, and synthetic materials such as filter fabric and impermeable HDPE liners. Materials facilitating drainage were placed in the Sunlight, Arkose Valley, Midas and North Borrow Spring areas and will minimize potential impacts to water quality.

4. Tailings were not placed directly in WUS but a portion of the impoundments were sited over WUS. Tailings impoundments were constructed by excavating a portion of the impacted WUS which were then filled using gravel underdrains capped by native, compacted clays from local borrow sources (Tailings Impoundment No. 1). At Tailings Impoundment No. 2, native, non-reactive material is overlain by a 60 mil HDPE liner.

Under the Proposed Action, 1.78 acres of additional non-wetland WUS will be filled by material excavated at the mine. In general, the geology of the Golden Sunlight Mine site is complex (see Section III.A in the EIS). Parent materials underlying the East Waste Rock Dump, where the majority of the fill to WUS will occur, are Precambrian and Paleozoic sandstones, shales and limestone, overlain and intruded by tertiary deposits of volcaniclastic, interfluvial, eolian and lacustrine origin. Outcroppings of limestone, shale, quartzite, sandstone, volcaniclastics, ferricrete, igneous intrusives and igneous extrusives occur throughout the area.

2.2.2 Section 230.11(b) - Water Circulation, Fluctuation, and Salinity Determinations

Surface water quantity and quality is discussed in Section III.B of the EIS. Surface water occurs in the Golden Sunlight Mine vicinity as seepage where groundwater exfiltrates from locally high water tables, fractures in underlying bedrock formations, or at contact points between subsurface strata. These springs flow no further than 300 feet downgradient from their sources before infiltrating. Spring water quality is variable and dependent on location, but usually reflects the reduced sulfide-rich subsurface environment of the area. High dissolved metal concentrations, high TDS, and low pH characterize naturally flowing spring water.

Four (of ten) seeps have been impacted by mining operations through completion of the *Interim Dump Plan*. Gravel or neutral rock trenches and engineered systems have been used at these sites to isolate spring water from water originating on mine sites. Though there has been loss of 0.059 acre of wetland habitat associated with these springs, there are no impacts to water quality, and recharge from these springs into groundwater resources has been preserved.

Additional surface water flows occasionally in the ephemeral draws during high intensity convective storms, usually once or twice each year. GSM's water management program actively routes this water away from areas disturbed by mining activities, and usually back into the same draw where the water originates. GSM's Water Management Plan is presented in Appendix A. GSM's SWPPP details on-site BMP's and structural controls designed to minimize water quality degradation from storm water discharge. Stormwater controls are summarized in Section II.B.1.a of the EIS.

The Proposed Action will route storm water from Sheep Rock Creek to the northeast and into a tributary to Conrow Creek. Peak flow for one-half the probable maximum flood (PMF) has been estimated at 976 cubic feet per second (cfs) in Sheep Rock Creek and at 2,756 cfs for Conrow Creek where diverted flow from Sheep Rock Creek would join Conrow Creek.

Storm water runon in the pit area is collected in the pit, removed through pit dewatering sumps, and directed into the operational water treatment plant at the plant site for use in ore processing. Storm water runon in the waste rock dump areas is intercepted by diversion ditches and directed away from waste rock into areas that promote infiltration and recharge to the underlying groundwater system. Precipitation that falls directly onto unreclaimed waste rock dumps typically puddles and evaporates and/or infiltrates into the dump surface where it is driven back to the atmosphere from heat produced in exothermic oxidation reactions. Any runoff that does occur directly from unreclaimed dumps and the tailings impoundment areas is contained by berms, and evaporates and/or infiltrates.

2.2.3 Section 230.11(c) - Suspended Particulate/Turbidity Determinations

Discharge of surface water from the Golden Sunlight Mine site results from high intensity thunderstorms. No non-storm discharge of surface water from the project area occurs. Sediment entrained in storm water comprises the chief constituent of concern for storm water quality, and is addressed in detail in the Storm Water Pollution Prevention Plan (SWPPP). In general, the SWPPP describes the potential sources of pollution and protection measures designed to prevent off-site impacts from storm water runoff originating at the mine.

Best Management Practices (BMPs) used for sediment control minimize the potential for sediment entrainment, encourage infiltration of storm water, reduce water velocities, and physically retain sediment. These include interceptor dikes and swales, diversion ditches, straw bales and rock check dams, sediment traps, berms, infiltration basins, energy diffusers, surface roughening, and reclamation by recontouring and planting. Reclamation of abandoned areas and temporary stockpiles is concurrent with mining operations.

2.2.4 Section 230.11(d) - Contaminant Determinations

As described in Section IV.B of the EIS, the proposed discharge of fill from mine activities would not introduce contaminants into WUS. As noted, the springs which have already been filled under the *Interim Dump Plan* will not be hydrologically connected with material other than neutral drain rock placed directly in the springs. The non-wetland WUS designated for the proposed fill activities only convey water during high intensity storms. This water would be routed around waste rock dumps. Sediment laden runoff from mine features and facilities is managed as described in the section above.

2.2.5 Section 230.11(e) - Aquatic Ecosystem and Organism Determinations

Aquatic resources on the site disturbed by mining operations are those associated with the four springs filled prior to the 1995 Settlement Agreement, which constitute 0.059 acre of disturbance to wetland WUS. The aquatic ecosystems of each of these springs were small, isolated, and disconnected to other aquatic systems. Organisms are limited to periphyton (mostly diatoms and blue-green algae) and invertebrates. No amphibians were observed during wildlife monitoring visits.

Non-wetland WUS addressed in the EIS are 1.78 acres of ephemeral drainages that would be impacted by the proposed placement of waste rock fill material. WUS indicators for these drainages are limited to evidence of sediment transport indicating surface flow. Wetland indicator species and hydric soils are lacking from these drainages, and aquatic communities

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associated with wetlands are absent. A few scattered cottonwood, mainly in Sheep Rock Creek, do indicate a perennial source of water within the root zone for these trees.

Water circulation and fluctuation will not be affected by the Proposed Action, except where fill is discharged. GSM's Water Management Plan will route water around fill areas, and with the exception of Sheep Rock Creek, return the water to the drainage from which it originates. Water originating above the East Waste Rock Dump in Sheep Rock Creek will be routed to the Conrow Creek drainage. Sheep Rock Creek is a tributary to the Jefferson Slough. Conrow Creek flows toward the Boulder River; however, discharge of flows from Conrow Creek into the Boulder River has never been observed as the creek drains into pastureland before reaching the river. Runoff that contacts waste rock dump surfaces does contain by-products of ARD reactions located on the surfaces of the waste rock; however, ARD production by this mechanism is considered negligible and BMP's at the mine site contain and direct runoff from the dumps to minimize impacts (see Section IV.B.1.a).

There are no fisheries on the Golden Sunlight Mine site which have been or will be impacted by discharge of fill into WUS.

2.2.6 Section 230.11(f) - Proposed Disposal Site Determinations

As previously stated, the MDEQ provides Section 401 certification pursuant to Section 401 of the Clean Water Act. The MDEQ will review the placement of fill material requested in the 404 permit application, and will make a determination for violations of applicable state water quality standards.

Approximately 1.78 acres of non-wetland WUS will be filled by placement of material. Fill areas have been sited with consideration for environmental, engineering and economic constraints. The fill sites are ephemeral drainages, storm water will be routed around fill material, and erosion controls and reclamation will maintain fill in its designated location. Therefore, dispersion of fill material into other naturally occurring WUS will not occur at the Golden Sunlight Mine site.

2.2.7 Section 230.11(g) - Determination of Cumulative Impacts on the Aquatic Ecosystem

Section IV.O in the EIS contains an analysis of cumulative impacts for wetland and non-wetland WUS. Cumulative impacts are those accruing from past, present and reasonably foreseeable future activities at the mine or in the local region. Cumulative impacts for the Golden Sunlight Mine facility include those attributable from the following:

1. The mining history in the Bull Mountains and at the Golden Sunlight Mine site prior to 1981;

2. The recent active mining at Golden Sunlight Mine beginning 1981 through completion of the EIS in 1997 (Operating Permit No. 00065 and amendments);

3. The continuation and expansion activities being addressed by this EIS through the Proposed Action.

4. Any subsequent expansion of operations reasonably anticipated beyond those addressed in this EIS; and

5. Reasonably foreseeable future activities proposed or under consideration by other entities in the region which may impact designated WUS.

Water quality impacts to WUS prior to 1981 may have occurred from historic adits exposing sulfide bearing formations to air and water. However, springs in the area not connected to or resulting from mine adits are characteristic of ARD, and differentiating historic baseline conditions (naturally occurring) from background water quality prior to Golden Sunlight Mine operations in 1981 is not feasible.

Impacts to WUS and water chemistry at Golden Sunlight Mine have been carefully documented and monitored since 1981. These include 0.059 acre of fill in wetland WUS and 2.46 acres of fill in non-wetland WUS through early 1996 which are addressed by the Consent Agreement signed in August 1996. An additional 0.62 acre of fill will be placed in non-wetland WUS by the end of the *Interim Dump Plan*. No significant degradation of water quality has occurred.

The activities under the Proposed Action include an additional 1.78 acres of fill discharged to non-wetland WUS. Mitigation activities have been ongoing since 1982. Approval of mitigation for fill discharged to WUS under all past activities and the *Interim Dump Plan* has been authorized by EPA, and COE. Authorization of fill activities for the Proposed Action is pending EPA and COE approval of the Mitigation Plan (Attachment 1) submitted by GSM.

GSM's operating plan for exploration, geotechnical and monitoring activities, approved by MDEQ and the BLM, includes a total disturbance area of 236 acres. Though no evaluation of WUS was made, any disturbance during exploration will be minor and temporary. Future disturbance to WUS resulting from future mining operations would necessarily be permitted under a separate Section 404 permit application.

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No activities by other entities on adjacent lands which may impact regional WUS are known or anticipated at this time.

2.2.8 Section 230.11(h) - Determination of Secondary Effects on the Aquatic Ecosystem

Because storm water flowing in the ephemeral drainages at Golden Sunlight Mine is routed around fill material, the hydrologic functions of the draws designated for placement of fill material will not be altered by the expansion proposal. Secondary impacts to water quality will be minimized by the erosion and sediment control practices used at Golden Sunlight Mine, and by the Water Management Plan presented in Appendix A. Monitoring of groundwater downgradient from tailings impoundments will ensure early detection and remediation of potential off-site threats to WUS.

Spring flows in the area may be impacted by pit dewatering. Reduced flows are likely in Steppan Spring and Steppan Original Spring. Rattlesnake Spring and Bunkhouse Springs may also experience reduced flows. The proposed groundwater capture system for the waste rock dumps could also cause reduced spring flows. Steppan Spring, Steppan Original Spring, and the unnamed spring in St. Paul gulch have a strong potential to be impacted. Sheep Rock and Beaver Springs have a minimal potential to be impacted. Potential spring flow reductions are addressed in the EIS in Mitigation Measure W-1.

2.3 Section 230.12 - Findings of Compliance or Noncompliance with the Restrictions on Discharge

Based on the data contained in the EIS, the determinations of the preceding section, and the remainder of this evaluation, placement of fill materials in non-wetland WUS as described in the Proposed Action would comply with the requirements of the Section 404 guidelines. Fill materials would be placed in non-wetland WUS primarily associated with expansion of the West Waste Rock Dump, the East Waste Rock Dump, and Tailings Impoundment No. 2. Disturbance to 1.78 acres of non-wetland WUS will occur if the COE grants a discharge permit under Section 404. However, judicious siting of fill areas, implementation of environmental protection measures, and ongoing mitigation for past and proposed Golden Sunlight Mine fill activity will compensate for loss of these WUS.

3.0 SUBPART C - POTENTIAL IMPACTS ON THE PHYSICAL AND CHEMICAL CHARACTERISTICS OF THE AQUATIC ECOSYSTEM

Potential impacts on the physical and chemical components of the aquatic environment resulting from filling operations have been evaluated for the Golden Sunlight Mine project. This section describes the results of this evaluation. A Mitigation Plan to offset the impacts associated with fills of wetland and non-wetland WUS under past and interim activities has been approved by the EPA and COE. A PDN and a 404 permit application for the 1.78 acres of non-wetland fill in the Proposed Action has been submitted to COE.

3.1 Section 230.20 - Physical Substrate Determinations

EIS Sections III.A and III.C describe the geology and soils at the mine site. Waste rock from the excavated pit comprises the fill material for this proposal. The placement of waste rock in the East Waste Rock Dump will create a terraced pad approximately 200 feet above pre-mine contours, with the main terrace at 5,360 feet elevation above Mean Sea Level and a smaller one south and east at 5,200 feet elevation. Additional waste rock will be placed to extend the east buttress, and additional tailings will enlarge Tailings Impoundment No. 2. The non-wetland WUS filled during these operations are the ephemeral channels on the site. Soil from drainages designated for fill will be stripped, stockpiled, and later used for reclamation of mine features.

3.2 Section 230.21 - Suspended Particulates/Turbidity

Sedimentation at Golden Sunlight Mine results primarily from high intensity convective precipitation when rainsplash impact and concentrated flows of water can dislodge and entrain sediment in moving water. The erosion and sediment control plan described in GSM's SWPPP incorporates both structural and non-structural BMP's to minimize entrainment and transport of sediment. All water originating on mine features (waste rock buttresses or dumps, roads, parking areas, and mine facilities) is subject to these controls prior to discharge into undisturbed swales.

The discharge of material into non-wetland WUS will not result in additional sedimentation to downstream WUS because water running onto these areas is diverted and routed away from fill material. In general, very little water runs off of the project site.

3.3 Section 230.22 - Water Clarity, Nutrient Load, and Chemistry

The discharge of waste rock into the ephemeral drainages at the site will not affect the water clarity or chemistry of these waters for the reasons mentioned in Section 3.2, above. Nutrient loading to WUS from discharge of fill into the draws at Golden Sunlight Mine will not occur due to these same controls.

3.4 Section 230.23 - Current Patterns and Water Circulation

Water circulation at the Golden Sunlight Mine site will be changed locally where fill is placed in ephemeral draws. Water routed around fill material will be discharged back into the draws below the fill, except in the case of Sheep Rock Creek where water will be routed to a tributary of Conrow Creek. Sheep Rock Creek is a tributary to the Jefferson Slough, and Conrow Creek flows toward the Boulder River above its confluence with the Jefferson Slough. Conrow Creek typically loses water before the junction with the Boulder River, draining into pastureland, and rarely discharges into Boulder River. Therefore, water diverted to Conrow Creek would be recharging the same aquifer downstream of its historic area of recharge.

In all cases, the draws' main function is to concentrate and convey water downslope to recharge areas of high infiltration capacity, usually in deeper alluvial and colluvial soils. Because these functions are preserved by GSM's water management plan, there will be no adverse effects on water circulation at Golden Sunlight Mine from the proposed fill. (See also Section 2.2.8 in this appendix regarding secondary effects of fill activities on WUS.)

3.5 Section 230.24 - Normal Water Fluctuations

Burial of draws at Golden Sunlight Mine and subsequent routing of surface flow will eliminate any environmental characteristic or value as a non-wetland WUS attributable to the filled draw. The time to peak flows below the filled areas may be increased due to a longer travel length for water routed around mine features, and the peak will likely be attenuated by erosion and sediment control features such as energy dissipating features or retention basins. Conveyance and infiltration of storm water to downstream recharge areas will not be significantly altered by the expansion.

3.6 Salinity Gradients

All fill materials are non-saline at the site, and all WUS in the vicinity of the project are freshwater. Therefore, no effect on salinity gradients is expected from the GSM proposal.

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4.0 SUBPART D - POTENTIAL IMPACTS ON BIOLOGICAL CHARACTERISTICS OF THE AQUATIC ECOSYSTEM

4.1 Section 230.30 - Threatened and Endangered Species

Sections III.F and IV.F of the EIS described the threatened and endangered species at the Golden Sunlight Mine site and the potential adverse impacts from each alternative under consideration. A detailed discussion is provided in the Biological Assessment (Appendix E). The analysis identified five federally listed species, two federal candidate species, and five BLM sensitive species (formerly classified by the USFWS as candidate-category 2 species) potentially occurring in the mine vicinity (see EIS Table III-4). None of these are aquatic species.

Non-aquatic species identified would not be affected by the proposed fill of 1.78 acres of ephemeral drainages at Golden Sunlight Mine. Proposed activities would result in an incremental loss of potential foraging habitat for peregrine falcon, bald eagle, northern goshawk, and ferruginous hawk, but the level of impact is considered insignificant. Short-term loss of potential breeding habitat for the mountain plover could occur, but is considered insignificant due to the lack of known occurrence in the project area and the abundance of similar habitat adjacent to the mine area. Sensitive bat species could be impacted by disturbance of abandoned shafts or adits, which provide potential habitat (see EIS Mitigation Measure WF-2). The formation of the pit pond following mine closure represents a potential impact to trumpeter swans, other bird species, and sensitive bat species that may be attracted to the poor quality pit water (see EIS Mitigation Measure WF-1).

4.2 Section 230.31 - Fish, Crustaceans, Mollusks, and Other Aquatic Organisms in the Aquatic Food Web

No fish species are found within the proposed site boundary for the Golden Sunlight Mine expansion, and aquatic species are limited to isolated invertebrate populations inhabiting the remaining springs. No amphibian species have been recorded, though they may occur periodically at the springs.

Potential impacts to fish species off-site could occur from off-site migration of ARD into surface waters in the Jefferson or Boulder Rivers. The objective of GSM's Water Management Plan (presented in Appendix A) is to: 1) limit the formation of ARD; and 2) minimize any ARD which is generated from migrating outside the project area. The Water Management Plan and the measures described in EIS Mitigation Measure W-4 are expected to minimize potential long-term ARD impacts to fishery resources.

Sedimentation of on-site springs and the Jefferson and Boulder Rivers could have adverse impacts to invertebrate populations, and could affect spawning of fish in the Jefferson and Boulder Rivers. However, GSM's erosion and sediment control measures have been effective in minimizing entrainment and transport of sediment.

4.3 Section 230.32 - Other Wildlife

GSM is proposing to discharge fill material into 1.78 acres of non-wetland ephemeral drainage area within the Golden Sunlight Mine project boundary. The habitat value of these draws is not unique within the site, and as such, will not disrupt the migration of large mammal species (deer, antelope, elk) or upset the foraging habits of raptors, waterfowl, or other bird species.

The tailings impoundments pose a threat to waterfowl which are attracted to the open water, and to other wildlife which may attempt to use impoundments as watering holes. GSM has an active 24-hour-a-day wildlife hazing program (described in Section II.B.1 in the EIS) which minimizes wildlife usage of the impoundments, and monitors and records any illnesses or mortalities that occur. The same risk would occur for wildlife attracted to the pit pond, and a hazing program may be required in this area as well (see EIS Mitigation Measure WF-1).

Between 1982 and 1994, 0.059 acre of wetland habitat (four springs) were filled, and loss of watering areas for wildlife may have occurred. GSM has been implementing mitigation since 1982 to compensate for this and other non-wetland fills. At this time, approximately 0.05 to 0.1 acre of wetlands have been created offsite at two locations, and nearly 150 acres of riparian area at two other locations have been fenced and managed to promoted recovery of eroding streambanks and riparian vegetation impacted by cattle grazing. In addition, GSM has purchased or leased over 5,600 acres of land in the region, and is working with local, state, and federal agencies to develop wildlife management plans for these areas, including enhancement of wetland and WUS values.

Additional watering sites for wildlife at area springs may be affected by long-term ARD from the waste rock dumps or reduced spring flows resulting from pit dewatering or drawdown associated with the proposed groundwater capture system (see EIS Mitigation Measure W-1).

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5.0 SUBPART E - POTENTIAL IMPACTS ON SPECIAL AQUATIC SITES

As defined in CFR Section 230.3(q-1), *special aquatic sites* are those possessing special ecological characteristics of productivity, habitat, wildlife protection, or other important and easily disrupted ecological values. In general, these sites are infrequent on the Golden Sunlight Mine site, and would be limited to the previously filled seep wetlands.

5.1 Section 230.40 - Sanctuaries and Refuges

No sanctuaries or refuges exist within the project area.

5.2 Section 230.41 - Wetlands

As previously mentioned, 0.059 acre of spring-fed wetland area has been filled at four springs by GSM mining operations between 1982 and 1994. These discharges are being addressed by the Consent Agreement with EPA and an "after-the-fact" 404 discharge permit from the COE. Ongoing and proposed mitigation in GSM's Mitigation Plan (Attachment 1) will compensate for the loss of the wetland habitat at Golden Sunlight Mine.

Fill activities under the proposed alternative will occur in 1.78 acres of non-wetland WUS (ephemeral drainages). These drainages reflect the upland environment found at the site rather than an aquatic environment characteristic of wetland WUS.

5.3 Section 230.42 - Mud Flats

There are no mud flats at the project site.

5.4 Section 230.43 - Vegetated Shallows

There are no vegetated shallows at the project site.

5.5 Section 230.44 - Coral Reefs

There are no coral reefs at the project site.

5.6 Section 230.45 - Riffle and Pool Complexes

There are no riffle and pool complexes associated with the drainages in the project site.

6.0 SUBPART F - POTENTIAL EFFECT ON HUMAN USE CHARACTERISTICS

6.1 Section 230.50 - Municipal and Private Water Supplies

Proposed continuation and expansion of mining will not affect municipal or private water supplies. As mentioned in Sections 2.1.2 and 2.1.3, a defect in the slurry cut-off wall from Tailings Impoundment No. 1 introduced cyanide contamination into groundwater which was observed at private wells in the area. The situation was remedied by installation of monitoring and pumping wells immediately downgradient of the impoundment. If contamination is detected below the impoundment, the pumping wells can be used to pump seepage from the impoundment for use in the process during mine life. After mining, seepage from both tailings impoundments will be routed to the water treatment plant. GSM is implementing an INCO/SO_2 system in 1997 to reduce cyanide in Tailings Impoundment No. 2.

6.2 Section 230.51 - Recreational and Commercial Fisheries

No recreational or commercial fisheries exist within the project boundaries. Off site enhancement of riparian habitat on lands acquired by GSM should improve recreational fishing in the vicinity.

6.3 Section 230.52 - Water-Related Recreation

No water related recreation exists within the project boundaries. Improved opportunity for water-related recreation will exist at two off-site parcels purchased by GSM upon completion of resource management plans for these sites.

6.4 Section 230.53 - Aesthetics

The discharge of fill into 1.78 acres of ephemeral drainage will have little to no incremental effect on the disturbance already permitted at Golden Sunlight Mine. Operating Permit No. 00065 permits activities through completion of the EIS and allows 2,336 acres of disturbance within project boundaries. The Proposed Action increases disturbance to 2,964 acres and increases WUS impacts to 4.9 acres. The draws subject to additional fill under the proposed continuance and expansion of mining operations constitute less than 0.08 percent of the total disturbance within project boundaries.

6.5 Section 230.54 - Parks, National and Historical Monuments, National Seashores, Wilderness Areas, Research Sites, and Similar Preserves

No areas designated for their aesthetic, educational, historical, recreational, or scientific value will be affected by the proposed discharge of fill at Golden Sunlight Mine.

7.0 SUBPART G - EVALUATION AND TESTING

7.1 Section 230.60 - General Evaluation of Dredged or Fill Material

Waste rock extracted from the open pit and discharged into non-wetland WUS contains sulfide bearing minerals with the potential to create ARD if exposed to air and water (see EIS Section III.A). ARD also occurs naturally at some springs on the site, and reflects the geology underlying the area. GSM's Water Management Plan (Appendix A) includes measures to minimize the production of ARD from waste rock.

7.2 Section 230.61 - Chemical, Biological, and Physical Evaluation and Testing

EIS Section III.A. describes the geology at the Golden Sunlight Mine site, including the chemical properties of waste rock used as fill material. Over 350 samples of waste rock have been tested as part of an oxide rock characterization program, implemented to select and segregate potential capping material for mine reclamation. The tests sort waste rock by source and material handling classification using acid-base accounting (ABA), net acid generating pH (NAG), and humidity cell tests. Results of these tests can be found in the operating permit for the mine (GSM 1995).

No material will be discharged into standing WUS, and therefore, no water column effects or effects on benthic species will occur.

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8.0 SUBPART H - ACTIONS TO MINIMIZE ADVERSE EFFECTS

Section 2.1.4 of this appendix describes the appropriate and practicable steps taken to minimize potential adverse impacts of the discharges of fill material on the aquatic ecosystem. Mitigation and environmental protection measures also are referred to in other sections as well. Section II.B.1 in the EIS describes mining operations through the completion of the *Interim Dump Plan* (the No Action Alternative) and necessary precautions used to minimize potential adverse impacts associated with mining activities. Section IV.P in the EIS describes measures for monitoring and mitigating adverse impacts.

Mitigation for "after-the-fact" fill of wetland and non-wetland WUS discharged prior to 1994 is addressed by the Consent Agreement with EPA. A COE permit for fill of non-wetland WUS during the *Interim Dump Plan* was issued in January 1997. Mitigation proposed for the 1.78 acres of non-wetland WUS designated to be filled under the Proposed Action (Attachment 1) is similar to that proposed and authorized for past and interim fill activities. GSM mining activities will have filled a total of 0.059 acre of wetland WUS and 4.86 acres of non-wetland WUS (assuming the Proposed Action is selected) when mining operations cease in 2006.

8.1 Section 230.70 - Actions Concerning the Location of the Discharge

Environmental, engineering and economic criteria were considered when siting of mine facilities, waste rock dumps and tailings impoundments at Golden Sunlight Mine was evaluated. The Proposed Action represents an optimum defined by the constraints posed by these criteria. Environmental considerations attempted to minimize the disturbance to wetland and non-wetland WUS. In addition, the potential impacts to air, water, soil and subsequent impacts to human health, terrestrial vegetation and wildlife were considered. An important engineering consideration was to preserve the stability of the area where ground movement occurred in 1994 by avoiding the use of this area for waste rock dumping.

8.2 Section 230.71 - Actions Concerning the Material to be Discharged

Waste rock extracted from the open pit is high in sulfide minerals and has the potential to produce ARD. Protection measures which will minimize or avoid the production of ARD from waste rock dumps focus on minimizing the contact of waste rock and water, and minimizing the movement and migration of water that does contact sulfide material in waste rock dumps.

Diversion trenches capture and convey water flowing on waste rock dumps quickly off waste rock. Storm water flow down natural draws is diverted and routed away from waste rock prior to contact. These measures ensure that minimal ARD will be produced at Golden Sunlight Mine. In addition, monitoring wells downgradient of the mine will allow early detection of migrating ARD, and pumping wells in the same areas will remove and treat ARD detected. The proposed groundwater capture system is described in EIS Appendix L. Long-term water treatment will be necessary to ensure compliance with Montana Water Quality Standards (see Appendix A).

8.3 Section 230.72 - Actions Controlling the Material After Discharge

The actions described above (Section 8.2) will minimize degradation to WUS from the discharged material by ensuring water quality protection on and off the Golden Sunlight Mine site. Reclamation of disturbed surface features at the mine is described in Section II.B.2.b in the EIS.

Reclamation will ensure that discharged material is stabilized. The reclamation plan will cap reclamation areas with oxidized cap rock and stockpiled native soils, contour slopes to between 3:1 and 2:1 grade, and plant native vegetation suitable for wildlife habitat and forage. Reclamation under the proposed plan will use soil with 20 percent coarse rock fragments on waste rock dump slopes to maximize slope stability and reduce erosion. If ABA and NAG pH testing indicate additional protection against ARD formation is warranted, the top 6 inches of waste rock will be limed to neutrality or another 6 inches of oxide waste rock will be added. A minimum of between 19 and 24 inches of soil is placed over cap rock as a growth medium for vegetation.

Tailings impoundments are reclaimed by capping with 24 inches of suitable oxidized or $CaCO_3$ rich material and 24 inches of subsoil or soil suitable for vegetation, subject to MDEQ and BLM criteria. Test plots on Tailings Impoundment No. 1 indicate that a clay layer is not necessary to prevent water from infiltrating the impoundment. Wherever feasible, reclamation of past disturbance areas are concurrent with mining operation.

8.4 Section 230.73 - Actions Affecting the Method of Dispersion

Under the Proposed Action, material discharged into non-wetland WUS would be placed with conventional mining equipment (dozers, loaders, dump trucks, scrapers) in accordance with an approved Section 404 permit from the COE.

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8.5 Section 230.74 - Actions Related to Technology

Appropriate technology will be utilized when fill is placed, and continued compliance with Montana Water Quality Standards may utilize developing technologies in water quality treatment methods. All surface water diversion and retention structures are designed and installed with modern methods. Sediment and erosion control features use both passive and active technologies. Testing of new technologies is concurrent with mining operations, and monitoring of water quality and vegetation on previously reclaimed sites allows for adjustments and improvements in the water management and reclamation plans at Golden Sunlight Mine.

8.6 Section 230.75 - Actions Affecting Plant and Animal Populations

The proposed continuation and expansion of mining operations at Golden Sunlight Mine will fill an additional 1.78 acres of non-wetland WUS. The designated fill areas are ephemeral draws with habitat value essentially the same as the adjacent uplands. Their designation as WUS is indicative of their hydrologic role as sites of conveyance and recharge rather than their value as wetland or riparian habitat. The hydrologic role is being preserved by routing and infiltration of storm water on-site, and their habitat value is more than replaced by the mitigation features described in Section 2.1.4.

8.7 Section 230.76 - Actions Affecting Human Use

No water-related recreational or commercial activities occur on the Golden Sunlight Mine site that will be affected by the proposed discharge of fill.

8.8 Other Actions

GSM has incorporated surface water diversion features onto fill sites and in natural drainages upgradient of fill sites to minimize potential adverse impacts associated with ARD formation. Long term monitoring and reclamation of areas disturbed by Golden Sunlight Mine operations will ensure the viability of habitat in perpetuity. Mitigation of unavoidable adverse impacts to wetland and non-wetland WUS will compensate for on-site losses to WUS resulting from Golden Sunlight Mine activities (see Attachment 1).

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9.0 PRELIMINARY CONCLUSIONS

This Appendix evaluates the environmental effect of the discharge of fill into 1.78 acres of non-wetland WUS proposed by the continuation and expansion of mining operations at Golden Sunlight Mine through 2006. A Consent Agreement signed by GSM and the EPA addresses "after-the-fact" fill activity of 0.059 acre of wetland WUS and 2.46 acres of non-wetland fill which occurred at the mine prior to early 1996. A COE Nationwide Permit No. 32 permits those fills. A Nationwide Permit No. 26 Section 404 permit was issued by the COE for fill activities of 0.62 acre of non-wetland WUS scheduled to occur during implementation of the *Interim Dump Plan*. An additional 404 permit application was filed for fill of 1.78 acres of non-wetland WUS under the Proposed Action. A total of 4.86 non-wetland acres and 0.059 wetland acre of WUS would be filled by all mining activities at Golden Sunlight Mine through the completion of mining operations in 2006.

This appendix has outlined and addressed each item that the COE must address when considering the issuance of a Section 404 permit authorizing the discharge of fill into designated WUS. These guidelines (Part 230 CFR codifying Section 404[b][1] of the Clean Water Act) itemize the issues which should be considered in order to restore and preserve the chemical, physical and biological integrity of WUS through the control of discharges of fill material.

The Proposed Action Alternative for this analysis would discharge fill material, primarily waste rock from the open pit, into 1.78 acres of non-wetland WUS. The 1.78 non-wetland acres are ephemeral draws which flow only during high intensity convective storms, once or twice each summer. Their primary functions are to convey and infiltrate storm water runoff. Vegetation within these draws reflects the adjacent upland environments rather than hydrophytic vegetation usually associated with wetland environments. Though draw vegetation may be transitional between the aspects it divides topographically, it is not transitional between the terrestrial and aquatic environments, and is therefore of low to insignificant value as wetland habitat.

Environmental protection and water quality management measures as indicated in this Appendix, Section II.B of the EIS, Appendix A (Water Management Plan), the Predischarge Notification, and GSM's SWPPP ensure that due diligence and proper precaution will be taken to minimize or avert water quality degradation from occurring as a result of mining operations and fill activity at Golden Sunlight Mine. A Mitigation Plan (Attachment 1) for unavoidable adverse impacts to WUS will compensate for losses to habitat or functional value of these waters. Concurrent and proposed future reclamation will ensure that functional values of ephemeral draws considered

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for filling are not impaired, and that habitat value of these draws and other on-site habitat is retained in perpetuity.

ATTACHMENT 1

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MITIGATION PLAN FOR PROPOSED PLACEMENT OF FILL MATERIAL INTO 1.8 ACRES OF JURISDICTIONAL NON-WETLAND WATERS OF THE UNITED STATES

GOLDEN SUNLIGHT MINES, INC.
JEFFERSON COUNTY, MONTANA

SUMMARY

This mitigation plan was prepared to accompany an application to the U.S. Army Corps of Engineers (COE) for a Nationwide Permit 26 to authorize a proposed discharge of 1.8 acres of fill material into headwaters and isolated waters of the U.S. at Golden Sunlight Mines, Inc. (GSM). The discharge would begin in 1998 upon completion of GSM's Environmental Impact Statement and approval of a major amendment to its mine operating permit (Permit No. 00065).

The mitigation plan follows the format of the *Habitat Mitigation and Monitoring Proposal Guidelines Annotated Outline* developed by COE. Most of the information presented in this plan was collected previously by GSM and independent consultants for use in other permitting documents (GSM, 1995a, GSM, 1995b and MDEQ and BLM, 1996). The habitat assessment was performed by GSM scientists using EPA (1992) guidance and information collected from the previous studies.

The proposed discharge of fill into 1.8 acres of non-wetland waters of the U.S. (Exhibits 1 and 2) would occur exclusively in incised drainage features (gulches) that exhibit ephemeral surface water flow. These features are typically dry and contain water only in response to intense rainfall events that are generally infrequent and of short duration. The water that collects in these features during times of runoff eventually infiltrates into the bottom of the channel, and recharges the underlying regional groundwater system. There is no perennial or intermittent streamflow in the 1.8 acres of non-wetland, ephemeral channels that would be disturbed by GSM.

The mitigation for the loss of natural hydrological functions of the 1.8 acres of ephemeral channels is by replacement with constructed storm water channels. The constructed channels collect and convey ephemeral surface runoff to infiltration areas that recharge the underlying regional groundwater system. The mitigation for loss of habitat functions is by replacement with reclaimed areas. Reclamation at GSM consists of replanting previously disturbed areas with native vegetation to create foraging habitat for wildlife that occur in the area. As of February 1997, GSM has constructed over 5.7 acres of storm water channels, and has successfully reclaimed 79.8 acres of previously disturbed areas. GSM's mitigation approach replaces the functions that would be lost, and has been accepted as suitable mitigation by the U.S. EPA for previous placement of fill material into non-wetland waters of the U.S.

I. PROJECT DESCRIPTION

A. Location

The Golden Sunlight Mine is located approximately 5 miles northeast of Whitehall, Montana. Access to the site is via Highway 2 East, located adjacent to Interstate 90. Existing mining operations are located in Sections 19, 20, 28, 29, 30, 33, Township 2 North, Range 3 West, Section 6, Township 1 North, Range 3 West, and Sections 24 and 25, Township 2 North, Range 4 West.

B. Summary of Project

Open pit mining at GSM typically removes between 90,000 to 130,000 tons of material per day using conventional drill, blast, load and haul mining techniques. Approximately 2,500,000 tons of ore are hauled to the mill for processing each year. The ore is crushed to less than 0.008-inch diameter particles and leached in tanks using dilute sodium cyanide solution. The gold-bearing solution is then sent to activated carbon circuits for recovery of dissolved gold. The spent ore (tailing) is discharged as a slurry to an impoundment where the solids portion of the tailing slurry settles and the decant solution is recycled back into the ore processing circuit.

The waste rock (non ore) that is removed from the open pit during mining is placed in waste rock piles located along the east and west sides of Bull Mountain. To accommodate a proposed mine expansion, waste rock material would be placed within the east waste rock complex (northeast of open pit), and in a waste rock area southeast of the pit and north of the tailing area. Both of these areas are outlined on Exhibits 1 and 2. Placement of waste rock material in these two areas will cover a total of 1.8 acres of ephemeral drainage channels (non-wetland waters of U.S.). Approval for the mine expansion is contingent upon the outcome of an Environmental Impact Statement now in progress.

Reclamation of disturbed areas at GSM typically consists of recontouring the land surface, placing cover soil as appropriate, and planting native vegetation. Reclamation and plant growth has thus far occurred on approximately 79.8 acres as shown on Exhibits 1 and 2. Additional acres are presently undergoing reclamation by resloping and revegetating portions of the waste rock complex just north of the tailing area. At mine closure, a total of either 1,190 acres (EIS No Action Alternative) or 1,589 acres (EIS Proposed Action Alternative) will have been reclaimed, depending on the final GSM mine plan that is approved by the Montana Department of Environmental Quality (MDEQ) and BLM.

The GSM project area is located in an open area of semi-arid climate with an average annual precipitation between 13 and 14 inches, and an average annual evapotranspiration rate of approximately 30 inches. The relatively small amount of annual precipitation is reflected by the absence of perennial streams in the area and the abundance of dryland vegetation.

The Jefferson Slough, which is tributary to the Jefferson River, is the major surface water feature near GSM. There is no perennial or intermittent stream flow out of the GSM project area. However, the GSM project area contains numerous incised drainage features (gulches) that exhibit ephemeral surface water flow in response to intense rainfall events that are generally infrequent and of short duration. Some drainages may experience short-term runoff several times a year, and others may flow only once every several years. All ephemeral drainage features near the area of proposed fills (Exhibits 1 and 2) are tributary to the Jefferson Slough.

GSM controls ephemeral, storm water flow that occurs near its mine facilities using a system of constructed collection/diversion channels. Presently, approximately 5.7 acres of constructed channels exist at GSM (Exhibits 1 and 2). This acreage will increase at mine closure to a total of either 6.4 acres or 7.9 acres of permanent diversion channels, depending on the final mine plan that is approved by MDEQ and BLM.

C. Responsible Parties

Golden Sunlight Mine, Inc.
453 Montana Highway 2 East
Whitehall, Montana 59759
Jerry Harrington, Mine Manager
Phone No. (406) 287-3257

Contact persons:
Troy Smith, Reclamation Specialist
Raymond Lazuk, Director of Environmental Affairs

D. Jurisdictional Areas Filled

A total of 1.8 acres of ephemeral drainage channels (non-wetland waters of U.S.) will be covered by placement of waste rock material. These areas were identified in a previous study (GSM, 1995b) and are shown on Exhibits 1 and 2.

E. Types, Functions, and Values of Jurisdictional Areas

1. Types of non-wetland waters of U.S.

The 1.8 acres of non-wetland waters of U.S. that would be affected by proposed placement of fill materials are typically dry, and are commonly referred to as gulches. They only contain water during extreme precipitation events, and the runoff that does collect in these features typically infiltrates into the subsurface as it flows down the drainage channel. In hydrologic terms, these drainage channels act as line-sources of recharge to the underlying regional groundwater system.

2. Functions and Values

Water Quality

The 1.8 acres of ephemeral channels at GSM are at elevations above the regional groundwater system. During times of runon, the surface water that collects within the drainage infiltrates into the bottom of the channel. This water then joins with the underlying regional groundwater system that flows radially away from Bull Mountain towards the Jefferson River. A storm water runoff sample was collected from the main channel below the proposed northeast waste rock expansion area (Sheep Rock Draw). The analysis shows that runoff is alkaline with low TDS (just over 100 mg/l) and with low but detectable trace metal concentrations.

Habitat

The 1.8 acres of ephemeral channels that would be filled by the proposed activity are typical of the channels found in the bottom of gulches within the GSM project area. The channel margins can host plant communities that offer foraging habitat for wildlife. The plant and animal species that occur within the general region of the GSM project area are described in detail by MDEQ and BLM (1996). Due to the infrequent occurrence of runoff, the ephemeral channels that would be disturbed by GSM do not provide a dependable source of water for wildlife. No riparian areas exist in these drainages and, subsequently, no aquatic plant or animal species are present. The only reliable water sources in the GSM project area are springs and wildlife/livestock watering troughs. The Jefferson Slough is the closest aquatic habitat for fish and amphibians in the general area of GSM.

The plant communities within gulches and adjacent upland areas at GSM consist of forbs, graminoids (grasses and grass-like plants), shrubs, and sparse stands of limber pine and Rocky Mountain juniper (DEQ 1996). There is no significant difference in amount of foraging habit between gulches and upland areas.

Mule deer reside year-round within the GSM project area boundary. Smaller numbers of elk, pronghorn, and white-tailed deer occasionally utilize habitat within the region. Other small mammal species that are known to occur within the general area include snowshoe hare, white-tailed jackrabbit, Nuttall's cottontail rabbit, yellow-bellied marmot, yellow pine and least chipmunk, Columbian ground squirrel, red squirrel , bushy-tailed woodrat, northern pocket gopher, porcupine, striped skunk, and several species of mice and vole.

Sharp-tailed grouse, mourning dove, and gray partridge are the only upland game birds recorded in the immediate vicinity of GSM. Twelve raptor species have been observed flying in the general area, and thirty-nine additional species of land birds have been recorded in the region. The prairie rattlesnake, bull snake, and western racer have been observed in xeric shrub/grassland, open grassland and rock habitats. No amphibians are known to exist in the GSM project area.

Visual observations by GSM personnel have not detected a preference by wildlife to frequent ephemeral drainages (gulches) over adjacent upland areas, since the foraging habitats are essentially the same. The springs that occur in the general vicinity of GSM, as well as the nearby Jefferson Slough, provide more valuable wildlife habitat as water sources than the ephemeral drainages onsite. The proposed fill activities of 1.8 acres at GSM also would have no direct or indirect effect on any threatened or endangered species such as the bald eagle or peregrine falcon, since the nearby Jefferson River system provides more habitat and food sources for these species.

c. Recreational Use

The proposed areas of disturbance (Exhibits 1 and 2) are used for mining and there is no public access within the mine area. Most of the land adjacent to the GSM project area is privately-owned, and public recreation opportunities are limited. GSM does allow public access to their lands outside of the project area for light, dispersed recreational use, primarily hunting.

II. GOAL OF MITIGATION

The goal of mitigation for the proposed activity that would fill 1.8 acres of non-wetland waters of the U.S is to replace lost hydrological and habitat functions. This has been accomplished as of February 1997 by creating 5.7 acres of storm water collection and diversion channels and by reclaiming 79.8 acres of previously disturbed areas with native vegetation. This work is described further in subsequent sections of this mitigation plan.

In addition to the replacement of hydrological and habitat functions mentioned above, GSM also has implemented other mitigation measures to minimize environmental impacts from its operations. This earlier mitigation work emphasized land acquisition and land use control to enhance wildlife habitat areas and preserve open space. These voluntary efforts are described below since they also may have direct applicability to satisfy Section 404 requirements.

GSM owns approximately 4,300 acres of land where the mine site is located, and initiated a land use management program of this area shortly after operations began with the goal of mitigating wildlife habitat loss due to mine development. The environmental mitigation actions taken within the mine site area since 1982 include the following:

1) Restrict fall cattle grazing of alfalfa hay land to provide mule deer range in the winter.
2) Restrict cattle grazing to 65% of range grassland and leave 35% for mule deer.
3) Create a wildlife watering system to help disperse mule deer during the fall.
4) Reclaim selected disturbance sites using native grasses and shrubs, with similar concurrent and final reclamation planned for all disturbance on site.

GSM also purchased the Candlestick Ranch located about four miles east of the mine area in 1989. The ranch includes approximately 3,200 acres of deeded land and approximately 1,900 acres of leased, state and federal land. The former owner of the ranch was planning to subdivide a portion of the property for a housing development. GSM's environmental mitigation goal for this area is to manage and develop the property for multiple use, with emphasis on wildlife habitat. GSM's mitigation actions within the ranch area are as follows:

1) Protect upland areas by leasing only irrigated portions of the ranch.
2) Fence approximately 146 acres of upland and riparian areas to prevent livestock damage and promote streambank stabilization.
3) Plant forage (grain strips) for waterfowl, pheasants and turkeys.
4) Impose vehicle travel restrictions of the area to encourage wildlife use (primarily elk).
5) Work with the Montana Department of Fish, Wildlife & Parks to transplant wild turkeys, collect Brown Trout eggs along the North Boulder River, develop trout spawning areas on ranch property, and develop a plan to open the entire ranch to hunting, fishing and other public recreational opportunities.

In 1991, GSM purchased the Piedmont Swamp (approximately 531 acres) southeast of Whitehall, Montana. A recent botanical evaluation of this site by the Montana Heritage Foundation documented a new addition to the state flora (one that also was federally listed as threatened) and two plant species of special concern. They also identified the area as having biodiversity features of state significance. Like the Candlestick Ranch, a portion of the Piedmont Swamp area was previously planned for a housing development. GSM's mitigation goal for this site is to preserve the wetland area for wildlife habitat. Mitigation actions taken by GSM since 1991 are as follows:

1) Fence the area to prevent livestock damage.
2) Remove old fencing materials, wooden structures and other debris from the area.
3) Allow public access for hunting, bird watching and other recreational activities.
4) Develop waterfowl nesting sites.
5) Begin developing a management plan to enhance the wetland area, and provide for additional recreational and educational opportunities with assistance from Ducks Unlimited, U.S. Fish and Wildlife Service, U.S. Soil Conservation Service, U.S. Bureau of Land Management, Montana Department of Fish, Wildlife & Parks, and the Skyline Sportsmen Association.

Most recently, GSM purchased 640 acres in the Bull Mountains approximately five miles north of the mine site in 1993. This land is in a known elk calving area and GSM intends to conduct mitigation measures such as fencing the area to control livestock use, restricting access during critical elk calving periods, and working with U.S. Bureau of Land Management and Montana Department of Fish, Wildlife & Parks to enhance elk and mule deer habitat, increase forage availability, and provide hunting and other recreational opportunities for the general public.

A. Type(s) of Habitat to be Created:

Specific mitigation for the proposed fill activity in 1.8 acres of ephemeral drainage channels has been accomplished by replacing hydrological functions using constructed storm water collection/diversion systems. These systems consist of a series of excavated or bermed channels that average 3-feet across. They function to collect and route ephemeral storm water flow away from mine facilities and towards adjacent hillsides, swales or natural drainages. These systems ensure that ephemeral runoff continues to recharge the underlying regional groundwater system and, more importantly, they maintain hydrologic isolation between precipitation runon and mine materials that have the potential to degrade water quality. As of February 1997, the 1.8 acres of ephemeral drainage channels that would be disturbed by the GSM's proposed action have been replaced by over 5.7 acres of constructed storm water collection/diversion channels (Exhibits 1 and 2).

Mitigation for loss of habitat in the 1.8 acres that would be disturbed by GSM also has been accomplished through reclamation of previous mine disturbance, primarily in the areas of waste rock piles. As of September 1996, approximately 79.8 acres of waste rock piles and adjacent land (Exhibit 1) were reclaimed by recontouring the surface, placing cover soil, seeding with native grasses and shrubs, and planting seedlings of Douglas fir, limber pine, and Rocky Mountain juniper. This reclamation work has created plant communities for wildlife habitat that is comparable to that found in the ephemeral drainages (gulches) and adjacent upland areas.

B. Functions and Values of Habitat to be Created

The hydrological functions of the 1.8 acres of ephemeral channels that are proposed to be filled have been replaced by storm water collection/diversion channels created by GSM (Exhibits 1 and 2). These systems collect and divert precipitation runon around mine facilities and back into natural drainages or into berms and swales to promote infiltration. Hydrologically, this is comparable to what occurs under a natural condition, whereby storm water recharges the underlying regional groundwater system.

Reclamation of previously disturbed areas has created plant communities that function in a similar capacity as in the ephemeral drainages (gulches) by providing wildlife habitat. These areas (Exhibit 1) were planted with a seed mix consisting of grass species that included wheatgrass, fescue, bluegrass and ricegrass, legumes such as alfalfa, sweetclover and sainfoin, and shrubs and forbs such as sagebrush, rabbitbrush and flax. In addition, GSM has planted seedlings of Douglas fir, limber pine, and Rocky Mountain juniper. Visual sightings by GSM, MDEQ and BLM confirm that the reclaimed areas are being used by wildlife.

C. Time Lapse

The mitigation work to replace the 1.8 acres of non-wetland waters of the U.S. has been completed as of February 1997.

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III. FINAL SUCCESS CRITERIA

A. Target Functions and Values

GSM has successfully replaced hydrological and habitat functions for the 1.8 acres of proposed disturbance. Ephemeral storm water channels have been constructed, and wildlife habitat created by reclamation of previously disturbed areas. GSM's post-closure reclamation plan (approved by MDEQ and BLM) will return the project area to similar pre-mining land/habitat uses.

B. Target Hydrological Regime

The storm water collection/diversion channels constructed by GSM function hydrologically to collect and convey storm water. This water remains within the same regional drainage basin as the proposed areas of disturbance and continues to recharge the same regional groundwater system. The overall water balance for the area is therefore maintained.

C. Target Jurisdictional Acreage to be Created

The constructed channels for storm water collection/diversion systems have similar function and appearance (i.e. definable bed and bank) as the channels within the proposed areas of disturbance. A total of 5.7 acres of storm water channels have been created as of February 1997.

IV. PROPOSED MITIGATION SITES

A. Location and Size of Mitigation Areas:

The ephemeral channels created by the storm water collection/diversion systems are generally located along major roadways (Exhibits 1 and 2). Segments of the collection/diversion systems exist adjacent to the areas of proposed disturbance. The reclaimed/revegetated wildlife habitat areas are located northwest, northeast and south of the open pit.

B. Ownership Status

All mitigation areas are owned or controlled (through MDEQ and BLM permit) by GSM. None of the sites currently carry either easement or encroachment rights. GSM will maintain ownership/control through mine closure and beyond. Should GSM relinquish its ownership, an easement would be placed on the area to protect and manage its intended long-term uses.

C. Existing Functions of Mitigation Areas

The mitigation sites are non waters of the U.S. that have previously been disturbed by past mining activities. Since the mitigation work has been completed as of February 1997, the functions of the mitigation sites are the same as in Section II.B.

D. Present and Proposed Uses of Mitigation Areas

The present uses of the mitigation areas are for storm water (ephemeral flow) control and wildlife habitat. These uses will continue after GSM discontinues mining, after which, the area also will become available for light recreational use.

E. Jurisdictional Delineation

The areas of constructed storm water channels and reclamation sites offered as mitigation for the proposed disturbance of 1.8 acres of non-wetland waters of the U.S. were not jurisdictional areas.

F. Present and Proposed Uses of All Adjacent Areas

GSM owns or controls (through MDEQ and BLM permit) all property adjoining the mitigation areas. The present uses of the adjacent areas consist of wildlife habitat and mining. The areas will continue to provide wildlife habitat, and will become available for light recreational use after GSM discontinues mining.

V. IMPLEMENTATION PLAN

A. Rationale for Expecting Implementation Success

Construction of storm water channels and reclamation work has been completed. Hydrological functions, revegetation success, and wildlife use has been observed by GSM, MDEQ and BLM.

B. Responsible Parties

Same as Section I.C.

C. Site Preparation

Storm Water (Ephemeral) Channels
The storm water collection/diversion systems at GSM are typically constructed by creating shallow, V-shaped or trapezoidal-shaped excavations alongside roadways. These create channels that average approximately three feet across. The channels intercept and convey ephemeral storm water flow to infiltration areas, or to other (natural) conveyances. These channels are used throughout the GSM project area (Exhibits 1 and 2). In some areas, the channels are lined with clay or plastic material to prevent contact between storm water runoff and chemically reactive waste rock material. The channels lead into swales, basins, or adjacent undisturbed drainages to promote infiltration of water into the subsurface.

Straw bales and/or rock check dams may be placed within the channels to reduce the velocity of ephemeral runoff, particularly on steeper grades. These structures are used throughout the project area, and are usually combined with upgradient sediment traps that promote ponding and infiltration of water to recharge the underlying groundwater system.

Reclamation/Habitat Creation

Portions of previously disturbed areas (Exhibits 1 and 2) were reclaimed by recontouring and placing approximately 1 to 2 feet of soil over the surface area to promote plant growth. Where needed, erosion control benches were placed across slopes to minimize erosion and intercept and convey storm water runoff.

After soil placement, the areas were fertilized and seeded with grass species that included wheatgrass, fescue, bluegrass and ricegrass; legumes such as alfalfa, sweetclover and sainfoin; and shrubs and forbs such as sagebrush, rabbitbrush and flax. As the grasses and shrubs became established, seedlings of Douglas fir, limber pine, and Rocky Mountain juniper were planted.

D. Planting Plan

The grass and shrub seed mixes were planted by broadcast seeding. In some areas a mulch (with tackifier) was used. All tree seedlings were hand planted. The seedlings were grown from seeds collected on or near the GSM project area. Rocky Mountain junipers are planted at a density of 20 to 50 plants per acre. Tree plantings are arranged in wind breaks and thickets that vary from 10 to 50 trees per acre. The north slopes are planted with Douglas fir, south slopes with limber pine, and the east and west slopes are mixed.

E. Schedule

All mitigation work to replace habitat for the proposed disturbance of 1.8 acres of non-wetland waters of the U.S. is complete.

F. Irrigation Plan

No irrigation is required for mitigation areas.

G. As-Built Conditions

The as-built conditions of the storm water collection/diversion systems and reclamation areas are shown on Exhibits 1 and 2. Additional details on storm water channel construction and reclamation activities are in GSM (1995a). Annual updates on storm water controls and reclamation are provided to MDEQ and BLM.

VI. MAINTENANCE DURING MONITORING PERIOD

A. Maintenance Activities

GSM conducts routine monitoring and maintenance (if needed) of all diversions and reclamation areas as a condition of its mine permit. This monitoring will continue until such time that the areas are deemed stable by MDEQ and BLM, and monitoring and maintenance are no longer necessary.

B. Responsible Parties

Same as in I.C.

C. Schedule

Monitoring of storm water channels and reclamation areas will be conducted monthly during operations, and annually following final reclamation and mine closure. Long-term monitoring will continue until such time that MDEQ and BLM consider final reclamation to be successful.

VII. MONITORING PLAN

A. Performance Criteria

The performance criteria are to maintain the target functions as described in Section III.A.

B. Monitoring Methods

The mitigation areas will be inspected monthly during operations, then annually following closure. The monitoring is to identify maintenance needs, and ensure the areas are functioning as previously described.

C. Annual Reports:

GSM describes reclamation activities in its Annual Report to the MDEQ and BLM.

D. Schedule

GSM's Annual Report is submitted to MDEQ and BLM within 6 months after year end.

VIII. COMPLETION OF MITIGATION

A. Notification of Completion

GSM has completed mitigation work to replace functions due to the proposed disturbance of 1.8 acres of non-wetland waters of the U.S. This mitigation plan provides notification that final success criteria have been met.

IX. CONTINGENCY MEASURES

The proposed disturbance area of non-wetland waters of the U.S. is 1.8 acres. As of February 1997, this acreage has been replaced by creation of new ephemeral storm water channels and reclamation to create new habitat areas. At mine closure, the acreage of constructed storm water channels will increase to either 6.4 acres or 7.9 acres (see attached maps), and the total acreage of reclaimed/revegetated area will increase to either 1,190 acres or 1,589 acres, depending on the final mine plan that is approved by the MDEQ and BLM. The total mitigation acreage at mine closure provides for a contingency measure.

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APPENDIX O

SCREENING LEVEL ECOLOGICAL RISK ASSESSMENT FOR SLUDGE DISPOSAL

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O-1 Conceptual Site Model of the Golden Sunlight Mine Sludge Disposal Area . . . . . O 3-8

1.0 INTRODUCTION

This document represents the results of a screening-level risk assessment (SLRA) of wildlife resources for the sludge deposition areas that will be established at Golden Sunlight Mines. The sludge deposition areas, or cells, will contain residual solids from a treatment plant designed to remove a significant portion of metals and other ions from mine pit water. This document examines risk associated with all likely routes of exposure for wildlife. It does not directly examine the potential risks to humans; however, the risks to human health, or the lack thereof, can be inferred from the subsequent text.

The risk to wildlife associated with any human activity is dependent upon 1) the concentration of any chemical of concern (COC) to which an organism may be exposed, 2) the route(s) of exposure, and 3) the duration of exposure. Organisms may be exposed to COCs via several possible routes, including water, sediment, and food ingestion. Exposure through any of these routes depends upon the clear presence of a complete exposure pathway. Should a pathway not exist, then exposure is not possible and there is an absence of risk, regardless of the chemical concentration.

While this SLRA is, in many ways, a conservative evaluation of risk, it also attempts to incorporate realistic assumptions regarding the likelihood of wildlife exposure to chemicals as well as the possible effects those chemicals may have. The methodologies used in this SLRA follow USEPA general guidance for conducting ecological risk assessments.

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2.0 RISK ASSESSMENT APPROACH AND METHODS SUMMARY

Methods for completing risk assessments (RAs) have been outlined in several USEPA, and other, documents (Norton et al. 1988; USEPA 1992; 1994; Wentsel et al. 1994). The procedures, however, can be adapted for specific situations and requirements. In general, Ecological Risk Assessment (ERA) methods are similar to those used for human health risk assessments, although assumptions may vary (e.g., protection of populations versus protection of individuals).

The RA framework can be divided into three phases or tasks: 1) problem formulation, 2) exposure and effects characterization, and 3) risk characterization. Each of these phases provides information to the next. Once the risk has been characterized, the information can be used in risk management.

2.1 Problem Formulation

Problem formulation may include, but not be limited to, the following tasks:

- site characterization
- identification of predicted or actual chemical concentrations
- identification of receptor organisms
- exposure scenarios
- conceptual site models

This information is needed to properly characterize exposure and effects in step 2 of the ERA process. Site characterization includes a description of the physical environment of the site, including the surface area of the contaminated area, treatment of the material, access to the area, and availability of alternate resources. Such information is typically derived from on-site surveys or project plans.

An important aspect of problem formulation is establishing the viability of exposure pathways. For example, a lake or pond may have concentrations of metals that are high enough to cause adverse effects to large mammals. However, if the site is isolated with a high fence that prevents access, then there is no exposure and therefore no risk.

2.2 Exposure and Effects Characterization

Exposure characterization involves the identification of the levels of contaminants that a receptor organism may be exposed to. These levels are then used in the ecological risk calculations. In a complete SLRA, all complete exposure pathways would be considered in calculating exposure (i.e., dose). Any risk assessment requires the application of certain assumptions regarding such things as 1) frequency of exposure, 2) ingestion rates, 3) body weight, and 4) effects thresholds.

Effects characterization includes the establishment of concentrations (or doses) of chemicals of concern that may cause adverse effects to receptor organisms. Effects data may come from several sources, including field investigations and laboratory toxicity studies. For most SLRAs, data are obtained from existing laboratory studies. Unfortunately, while receptor organisms are those species which are, or may be, found in the study area and thus exposed to chemicals of potential concern, toxicity data is generally available only on specific laboratory organisms. There is a relatively small pool of species that are typically used in laboratory studies, including the chicken, mallard duck, mouse, rat, and mink. Despite the limited number of test species, data from these tests can be extrapolated to wildlife species by the use of equations which accommodate differences in 1) body weight, 2) water ingestion, and 3) food ingestion.

2.3 Risk Characterization

The final phase of a risk assessment is the risk characterization. In this phase the likelihood that any adverse effects would occur is evaluated and, usually, quantified. For many SLRAs, risk is quantified by comparing the expected environmental dose (EED) to the effects threshold, sometimes referred to as a toxicity reference value (TRV). The resulting ratio is known as the hazard quotient (HQ). An HQ less than 1 indicates the concentration of a chemical of concern predicted to be present in the environment is less than the concentration that is expected to cause adverse effects. An HQ greater than 1 indicates that the possibility of adverse effects exists. However, it does not imply the adverse effects do exist, but only that further investigation may be necessary. Because of the conservative nature of the SLRA, HQs could exceed 1 and still not necessarily indicate adverse effects.

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3.0 PROBLEM FORMULATION

3.1 Site Characterization

The Golden Sunlight Mine lies in Jefferson County, Montana, northeast of Whitehall and northwest of Cardwell. The area around the mine is semi-arid, receiving approximately 12 inches of precipitation per year in the valley and 20 inches in the mountains. There are no perennial streams in the project area boundaries. To the east of the project area, the Boulder River runs south to join the Jefferson River. Both rivers are fed by snow melt; the Boulder River also receives water from one or more springs upstream of the Jefferson River confluence.

Water from both the pit and tailings pond at the mine will be treated continuously to remove constituents that are believed to be potentially hazardous. The water will be treated to allow for the precipitation of solids. The resulting solids, or sludge, will be further dewatered using a filter press. The resulting sludge will have a minimum solids content of 50% by weight. Sludge will be placed in solid waste disposal ponds or cells, which will be located on the surface of Tailing Impoundment No. 2. The cells will be lined with a 60 mil High Density Polyethylene (HDPE) liner.

In years 0 through 10, two, 184 foot square (34,000 ft^2) cells will be used. After year 10 cells will be 200x200 (40,000 ft^2). Cells will be bounded by 24 foot high compacted berms. Active cells will be surrounded by wildlife control fences (at least 8 feet high) to prevent large animals from gaining access to the sludge cells. Water reclaim ponds will be netted. There will be at least two cells active at any one time. Sludge will be deposited in one cell while the other is drying out or being compacted. During the drying process the sludge will be periodically disked to enhance the rate of evaporation.

Each cell will be filled until the sludge reaches a compacted depth of approximately 20 feet. At that time a geomembrane will be placed on the surface of the compacted sludge and capping materials that had been removed prior to cell construction will be replaced. The soil will then be revegetated.

3.2 Predicted Chemistry

Concentrations of chemicals predicted to be present in the sludge are not available. However, concentrations of some metals were measured in sludge extract using the Toxicity Characteristic Leaching Procedure (TCLP). Those concentrations are presented in Table O-1.

3.3 Habitats

Western Technology and Engineering (WESTECH) (1991) described seven wildlife community types in the Golden Sunlight area, the first six of which were initially described by Trout (1988). Those areas are:

- Juniper/Mountain Mahogany
- Douglas-Fir/Idaho Fescue
- Limber Pine/Juniper
- Big Sagebrush/Grass
- Needle and Thread/Blue Grama
- Bluebunch Wheatgrass/Idaho Wheatgrass
- Disturbed (e.g., grazing, roads, etc)

These communities may occur as isolated groups throughout the project area. However, as expected, much of the mine area is classified as disturbed due to intensive human activity, both current and historic. Even though much of the mine area, including the location of the sludge cells, is classified as disturbed, there are small areas of undisturbed habitat. When combined with reclaimed sites at the mine and considering the restricted human access of the mine itself, these areas create habitat for a variety of wildlife species that have adapted to the presence of humans and human activity.

WESTECH (1994) reported that 268 birds, 64 mammals, nine fish, six amphibians, and seven reptiles may possibly occur in the vicinity of Golden Sunlight Mine, based upon a review of previous studies. Species occurrence in the mine area was considered when selecting receptor species.

Table O-1

Toxicity Characterization Leaching Procedure (TCLP) Metal Concentrations Measured in Sludge from Golden Sunlight Mine

Metal	Sample Number/Date Collected			
	8-84[a] 08/27/93	8-85[a] 08/27/93	6[b] 09/01/93	8[b] 09/01/93
Aluminum	NM[c]	NM	0.52	NM
Arsenic	<0.5	<0.5	0.014	0.005
Barium	<10	<10	NM	NM
Cadmium	0.1	0.2	<0.001	<0.001
Chromium	<0.5	<0.5	NM	NM
Copper	NM	NM	0.496	NM
Iron	NM	NM	<0.05	NM
Lead	<0.5	<0.5	NM	NM
Manganese	NM	NM	<0.05	NM
Mercury	<0.02	<0.02	NM	NM
Nickel	NM	NM	0.062	NM
Selenium	<0.1	<0.1	NM	NM
Silver	<0.5	<0.5	NM	NM
Zinc	NM	NM	<0.05	NM

[a] Analyzed by Energy Laboratories.

[b] Analyzed by Mid-Continent Laboratories.

[c] NM = Parameter was not measured in this sample.

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3.4 Receptor Organisms

3.4.1 Guidelines for Selecting Receptor Species

An important link in the completion of an ERA is the selection of appropriate receptor species. The criteria for selection of receptors includes consideration of 1) taxonomic levels, 2) trophic levels, 3) habitats, and 4) body size. These factors are important since organisms that occupy different ecological niches may be exposed not only through different pathways, but also to different levels of contaminants. In addition, organisms that are deemed socially significant (e.g., threatened and endangered) may also need to be included as receptor species. The following section briefly describes which organisms have been identified as receptor species and the rationale for that selection.

The following species were selected as potential receptors to be included in the Golden Sunlight ERA:

Receptor Category	Common Name	Scientific Name
Mammals		
Small Herbivorous Mammal	Deer Mouse	*Peromyscus maniculatus*
Large Opportunistic/Omnivorous Mammal	Coyote	*Canis latrans*
Large Herbivorous Mammal/Big Game	Mule Deer	*Odocoileus hemionus*
Birds		
Omnivorous Ground-Feeding Bird	American Robin	*Turdus migratorius*
Bird of Prey	American Kestrel	*Falco sparverius*

These species were selected as representing several ecological niches and potential exposure pathways. Following is a brief discussion of each receptor species.

3.4.2 Deer Mouse

The range of the deer mouse covers most of the United States and Canada. It is generally found in dryland habitats and feeds on seeds, nuts, acorns, and insects (Burt and Grossenheider 1976). Body length of the adult is approximately 122 to 229 mm, including the tail; weight ranges from 18 to 35g. Deer mice were reported in the Golden Sunlight Mine area (WESTECH 1991). The deer mouse was included as a receptor species since it

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represents small herbivores that would not be restricted by institutional barriers such as a fence, and that are a food source for carnivores such as the coyote and raptors.

3.4.3 Coyote

Although at one time coyote populations were reduced over much of the western United States, the species has made a dramatic return and now can be seen, albeit rarely, as far east as the Atlantic coast. It is very common in the western United States, and was found to be present in the Golden Sunlight Mine study area (WESTECH 1991). Coyotes weigh between 9 and 22 kg; males tend to be larger than females. Coyotes are primarily nocturnal, although they may be seen during the day as well. The coyote is an opportunistic feeder and scavenger. It will eat plants and animals including juniper berries, mice, wood rats, antelope squirrels, and rabbits. Coyotes frequently seek out drinking water and may even dig down to reach it (Miller and Stebbins 1964).

Coyotes typically make, or use existing, dens for shelter and to raise young. Young are typically born in April and May. Coyotes may range over several square kilometers in search of food.

3.4.4 Mule Deer

The range of the mule deer covers all of the western great plains from Mexico into Canada. Mule deer are large herbivores, with males reaching weights of up to 180 kg, although average weights are approximately 93 kg. Adult females weigh approximately 70 kg. Although generally nonmigratory on the plains, in the mountains mule deer tend to move to higher ground in the spring and return to lower elevations in the winter. Mule deer were found on reclaimed, disturbed, and limber pine/juniper habitats during an August 2, 1991, survey (WESTECH 1991). Mule deer tracks and pellet groups were found in all habitats in every mine permit amendment.

The mule deer is primarily a browser during the winter, feeding on shrubs (e.g., sagebrush and mountain mahogany) and twigs. The proportion of grasses in the diet increases during the warmer months. Although mule deer can satisfy some of their water needs through their diet, they will ingest water directly. Availability of water can, in fact, influence distribution of deer (Hervert and Krausman 1986). Deer may utilize man-made water supplies such as cattle tanks (Ragotzkie 1988).

3.4.5 American Robin

American robins are thrushes that are found throughout the United States in a variety of habitats including woodlands, swamps, suburbs, and parks. Males and females are similar in size with an average weight of approximately 80 g (USEPA 1993). Robins, like most thrushes, are ground-feeding birds that eat worms, insects, and fruit. Robins have been observed at the Golden Sunlight Mine sight (WESTECH 1991). Robins represent a large group of ground-feeding birds that are primary and secondary consumers, and that might feed in the study area.

3.4.6 American Kestrel

It is common to include a raptor as a receptor species for risk assessments. Raptors represent top-level carnivores and thus are potentially at risk from chemicals that biomagnify. Like most raptors, male kestrels are slightly smaller than females. The mean weight of a female is approximately 130 g; the mean weight of a male is approximately 113 g (USEPA 1993). Kestrels feed on many kinds of animals, including insects, reptiles, small mammals, and birds. They are found in a variety of habitats from highly urbanized areas to remote locations.

The American kestrel was the only raptor observed at the mine site during the 1991 reconnaissance, although Golden Sunlight personnel reported seeing red-tailed hawks, golden eagles, and vultures (WESTECH 1991).

3.5 Wildlife Exposure Scenarios

For a receptor organism to be considered in the risk assessment there must be a significant and complete exposure pathway via one or more sources. After a review of the habits of the receptor species, and considering the structure of the site, it was concluded that no complete exposure pathways exist for the following reasons:

- A tall wildlife fence will surround the sludge cells when they are in operation. This fence will prevent access by all but the smallest mammals. Therefore, even though mule deer and coyotes may pass close to the sludge cells, they cannot enter the area.

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- There will be no vegetation growing in the sludge cells. After sludge has been deposited in a cell to a certain depth, the sludge will be left to dry out. During this time it will be periodically disked and then, when 20% moisture is reached, it will be compacted. Therefore, no vegetation will be allowed to grow. There will be nothing in the sludge cell to attract small mammals or herbivorous birds - no plants, seeds, fruit, etc. Soil faunal populations should also be essentially nonexistent since there will be very little organic matter for earthworms, isopods, collembolans, nematodes, etc., to feed on. Invertebrate-eating birds, like robins, will not be attracted to the sludge cells.

- The absence of small mammals and birds, insects, and reptiles will preclude the use of the sludge cells as feeding grounds for larger birds such as the kestrel. Other areas on and near the mine have much higher densities of prey species and will prove substantially more attractive than the sludge cells.

- Since all runoff water from the site will be collected and returned to the water treatment plant, there is no risk associated with soluble metals that might be found in the water.

- Once a cell is full, a HPDE liner will be placed over the sludge and the cell will be capped with original material removed from the site. It will then be revegetated. If capping is properly performed, the sludge will be isolated and should not pose a risk after closure.

3.6 Conceptual Site Model

As described in section 3.5, no complete exposure pathways were identified for wildlife at the Golden Sunlight Mine sludge treatment facility. The resulting conceptual site model is illustrated in Figure O-1. No risk to wildlife is anticipated from the sludge cells. The absence of risk is dependent upon maintenance of the facilities and institutional controls, such as the wildlife fence, runoff water collection system, sludge disking, and capping at closure. Should these control systems break down, the risk to wildlife may increase.

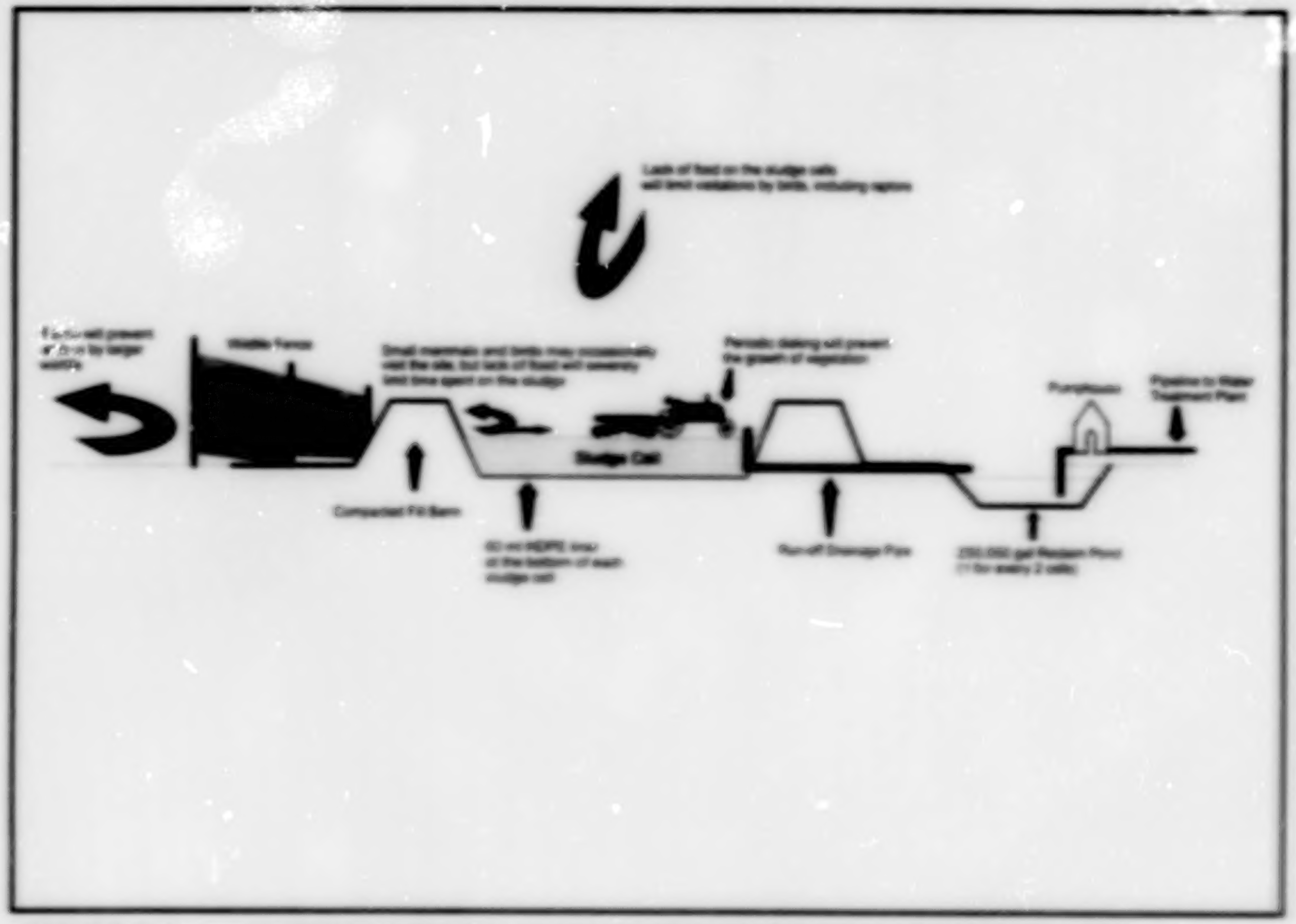
Lack of food on the sludge cells will limit visitations by birds, including raptors
Fence will prevent access by larger wildlife
Wildlife Fence
Small mammals and birds may occasionally visit the site, but lack of food will severely limit time spent on the sludge
Periodic disking will prevent the growth of vegetation
Sludge Cell
Pumphouse
Pipeline to Water Treatment Plant
Compacted Fill Berm
60 mil HDPE liner at the bottom of each sludge cell
Run-off Drainage Pipe
250,000 gal Reclaim Pond (1 for every 2 cells)

FIGURE O-1 CONCEPTUAL SITE MODEL OF THE GOLDEN SUNLIGHT MINE SLUDGE DISPOSAL AREA

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4.0 SUMMARY

In order to reduce concentrations of metals and other ions in pit lake and tailings impoundment water at the Golden Sunlight Mine in Montana, the water will be treated using chemical precipitation. The resulting sludge will be placed in large, open pits, or cells, to allow water to evaporate. After the sludge has reached a compacted depth of approximately 20 feet the cells will be capped and revegetated.

Although surveys have indicated that several species of mammals and birds can be found in the mine area, the sludge treatment cells will pose no risk to any species. The absence of risk is due to the lack of any complete exposure pathways. A wildlife fence surrounding the sludge cells will prevent large mammals from accessing the area. Because the sludge will be disked on a regular basis, vegetation is not expected to grow in the cells. There will, therefore, be no food to attract small mammals or birds. Although small mammals may occasionally pass through the cells and birds may land on the sludge, such visitations should be rare and will not constitute a viable exposure pathway.

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MONTANA DEPARTMENT OF ENVIRONMENTAL QUALITY
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HELENA, MONTANA 59620-0901

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DATE FILMED

08/20/03

STEPPHAN SPRING
PW-17
SOUTH ACCESS ROAD
PERMIT BOUNDARY
STEPPHAN ORIGINAL
SWSP-3A
PW-22
ACCESS ROAD
EFPB Well Area
TAILING IMPOUNDMENT NUMBER 1
GW-17
GW-49
GW-15
GW-19
GWG-1D
EPB Well Area
GW-65
TAILING IMPOUNDMENT NUMBER 2
SWSP-1A
ET-9
ET-11
GW-21
GW-58
GW-27
GW-28
GW-12
GW-50
EGW-4
GW-13
GW-16
GW-59
WPB-6
GW-39
18,000 N.
GW-52
18,000 N.
GW-10
GW-38
GW-25
GW-26
GW-54
GW-61
GW-60
GW-53
GW-23
GW-24
GW-30
GW-65
SPB Well Area
EGW-1
GW-62
GW-57
36
31
32
33
GW-51
EGW-7D

LEGEND

⌖	STORMWATER SITE
◬	SPRING / SURFACE WATER
•	MONITORING WELL
▪	GROUNDWATER PUMP BACK WELL
☒	PROPOSED MONITOR WELL
⊙	PRIVATE RESIDENCE WELL
⤙	DRAIN SYSTEM

GOLDEN SUNLIGHT MINES, INC.

FIGURE A1

HYDROLOGIC FEATURES AND
1997 MONITORING SITES

SOUTH HALF

DATE JULY 9,1997	*SCALE*	DRAWN BY D. SCHARF
REVISION	1" = 1100'	DRAFTED BY D. SCHARF
Contour Int. = 50'		SOUTH,NORTH-MONITOR

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1

FIGURE A2

HYDROLOGIC FEATURES AND 1997 MONITORING SITES

NORTH HALF

SCALE 1"=1100'

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2

PROPOSED PERMIT BNDY
CURRENT PERMIT BNDY
CURRENT PERMIT BNDY
PROPOSED PERMIT BOUNDARY
SHEEPROCK DRAW
HWY. 69
BOULDER RIVER
200' CONTOURS
50' CONTOURS
ST. PAUL GULCH
CURRENT PERMIT BOUNDARY
50' CONTOURS
200' CONTOURS
BOULDER RIVER

GOLDEN SUNLIGHT MINES, INC.

FIGURE A3

DRAINAGE MAP
SOUTH HALF

CONTOUR INTERVALS

NORTHCENTRAL (WITHIN PERMIT BNDY'S) 50'

WEST, SOUTH, EAST SIDES 200'

DATE JULY 22,1987	SCALE 1" = 3000'	DRAWN BY D. SCHARF
REVISION		DRAFTED BY D. SCHARF
REVISION		DWG. No.

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CONROW DRAINAGE
200' CONTOURS
50' CONTOURS
200' CONTOURS
40' CONTOURS
N

GOLDEN SUNLIGHT MINES, INC.

FIGURE A4

DRAINAGE MAP
NORTH HALF

DATE JULY 22,1987	SCALE 1" = 3000'	DRAWN BY D. SCHARF
REVISION		DRAFTED BY D. SCHARF
REVISION		DWG. No.

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EXISTING PERMIT BOUNDARY
WEST DUMP BOUNDARY
PIT
W FLANK
WEST DUMP
EAST DUMP
MILL
1B
3
BUTTRESS DUMP
PROPOSED PERMIT BOUNDARY
BOUNDARY
NORTH
SCALE
(In Feet)
2000
0
2000
(Approximate Only)
LEGEND
GROUNDWATER QUALITY REGION (DEFINED FOR CHARACTERIZATION OF AMBIENT WATER QUALITY DOWNGRADIENT OR PROXIMAL TO POTENTIAL DISCHARGE AREAS)

GOLDEN SUNLIGHT MINES, INC.
APPLICATION FOR SOURCE SPECIFIC
GROUNDWATER MIXING ZONE

AMBIENT GROUNDWATER QUALITY REGIONS

FIGURE
3-1

Hydrometrics, Inc. Consulting Scientists, Engineers and Contractors

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5

EXISTING PERMIT BOUNDARY
WEST DUMP BOUNDARY
EAST DUMP
PIT
MILL
WEST DUMP
PROPOSED PERMIT BOUNDARY
NORTH
SCALE
(In Feet)
2000
0
2000
(Approximate Only)
LEGEND

GOLDEN SUNLIGHT MINES, INC.
APPLICATION FOR SOURCE SPECIFIC
GROUNDWATER MIXING ZONE

WASTE ROCK DUMP
GROUNDWATER MIXING MODEL FEATURES

FIGURE
4-1

Hydrometrics, Inc. Consulting Scientists, Engineers and Contractors

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6

R4W
R5W
13
18
17
16
24
21
WASTE ROCK DUMP
PERIMETER
EXISTING PERMIT BOUNDARY
ACTIVE DUMPS
WEST DUMP
BOUNDARY
PIT
WEST
DUMP
BOUNDARY
PW-46
PW-45
EAST DUMP
MIXING ZONE
BOUNDARY
BUTTRESS
NORTH
SCALE
(In Feet)
2000
0
2000
(Approximate Only)
LEGEND
●PW-22 PROPOSED INTERIM COMPLIANCE MONITORING WELL
MIXING ZONE BOUNDARY

LEGEND
●PW-22 PROPOSED INTERIM COMPLIANCE MONITORING WELL
MIXING ZONE BOUNDARY
WEST DUMP
PW-46
PROPOSED PERMIT BOUNDARY
EAST DUMP MIXING ZONE BOUNDARY
DUMP
25
30
29
28
STEPPHAN ORIGINAL
PW-22
NO. 1 IMPOUNDMENT
NO. 2 IMPOUNDMENT
PROPOSED PERMIT BOUNDARY
DISTURBANCE AREA
WEST DUMP-WEST FLANK MIXING ZONE BOUNDARY
36
31
32
33
WEST DUMP-EAST FLANK MIXING ZONE BOUNDARY
PROPOSED PERCOLATION POND
PROPOSED WATER TREATMENT PLANT
OW-3
OW-2
T2N
T1N
1
6
5

GOLDEN SUNLIGHT MINES, INC.
APPLICATION FOR SOURCE SPECIFIC
GROUNDWATER MIXING ZONE

PROPOSED MIXING ZONE BOUNDARY AND INTERIM COMPLIANCE MONITORING LOCATIONS

FIGURE
5-1

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Hydrometrics, Inc. Consulting Scientists, Engineers and Contractors

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